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ADOPTION OF BIOENERGY CROPS, INCOME AND CONTRACT PREFERENCES AMONG FARMERS IN NORTHERN GHANA: THE CASE OF JATROPHA

BY

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DECLARATION

This thesis "**Adoption of bioenergy crops, income and contract preferences among farmers in Northern Ghana: the case of Jatropha",** is the result of research work undertaken by Lauretta Sandra Boade Guentang in the Department of Agricultural Economics and Agribusiness, University of Ghana, under the supervision of Dr. Akwasi Mensah-Bonsu, Dr. Irene S. Egyir, Mr. D.P.K. Amegashie and Dr. Jean-Hugues Nlom. It has never been submitted in whole or in part for any degree in this University or elsewhere. References to other people's work have been duly acknowledged.

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ABSTRACT

In order to solve the crisis faced by the energy sector in Ghana, Jatropha has been promoted as a panacea and promising crop for bioenergy generation. Like other crops, Jatropha cultivation comes with opportunities. The study aims at analyzing how Jatropha adoption influences the level of crop incomes of farmers and the preferences for production contracts in Northern Ghana. The first objective is to identify the factors explaining farmers' adoption and land allocation of Jatropha in Northern Ghana. The second objective is to identify the factors explaining farmers' decisions to adopt Jatropha either on fertile or marginal lands in Northern Ghana. The third objective of the study measured the impact of Jatropha cultivation on farmers' crop incomes in Northern Ghana. The fourth objective is to identify farmers' preferences for contracts attributes in Jatropha cultivation in Northern Ghana. A double hurdle model is used to analyze Jatropha adoption decisions and its extent, in terms of land allocated to the crop. A bivariate Probit model is also used to analyze Jatropha adoption decisions taking into account the type of land (fertile vs marginal). A Propensity Score Matching (PSM) method is used to measure the impact of adopting Jatropha on total crop incomes of farmers. Through a Discrete Choice Experiment (DCE), a Random Parameter Logit (RPL) model is used to identify farmers' preferences for contract to produce Jatropha. The results show that farm and farmer' characteristics (District, age, number of adult members in the household, off-farm activities, hired labour, gender, and distance to market), institutional factors (extension services, FBO and access to credit) and risk preferences have a significant role in explaining farmers' adoption decision on bioenergy crops such as Jatropha. The influence of these factors differs when the type of land used to grow the crop is taken into consideration. Factors such as District, off-farm activities engagement and credit access are significant only on marginal land though the number of adults in the household, education, hired labour, age, extension services, FBO and risk attitude are significant on fertile land only. The study also finds that Jatropha adoption significantly reduces the level of total household crop income per hectare of farmers. The study finds a significant and positive standard deviation coefficient for all contract attributes (written contract, support from the buyer in the form of "Seeds, technical training, fertilizers and pesticides only", "Seeds, fertilizers and pesticides only", "Seeds and technical training only" and renegotiation option) revealing then heterogeneity of preferences for these attributes among farmers. Farmers require an additional compensation ranging from GH₵ 0.16 to GH₵ 2.27 per kilogram of Jatropha harvested for the inclusion of these contract attributes. The promotion of Jatropha cultivation should to be properly regulated to avoid the use of fertile land for Jatropha cultivation. There is a need to develop appropriate strategies and a regulatory framework to harness the potential economic opportunities from Jatropha cultivation, while protecting rural people from converting part of their fertile lands to Jatropha cultivation at the expense of food crops.; the availability of institutional facilities such as access to credit to promote Jatropha adoption decisions on marginal lands will sustain farmers' interest in production. The study recommends Jatropha contract design based on written contract where the contents of the contract and risks between farmers and the investors (buyers) are clearly stated. A contract containing support from the buyer in the form of seed, technical training fertilizers and pesticides should be encouraged.

DEDICATION

To the Blessed Mother Mary for her unfailing intercession for my prayers

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Lauretta Sandra Boade Guentang

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LIST OF ACRONYMS

ATT	Average Treatment Effect on the Treated
CARA	Constant Absolute Risk Aversion
CIA	Conditional Independence Assumption
CSC	Common Support Condition
DCE	Discrete Choice Experiment
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FBO	Farmer Based Organization
GDP	Gross Domestic Product
GHAJA	Ghana Jatropha Project
Gwh	Gigawatt hours
IEA	International Energy Agency
IIA	Independence of Irrelevant Alternatives
IID	Independent and identically distributed
IPCC	Intergovernemental Panel of Climate Change
MTOE	Million Tonne Equivalent
NGO	Non-Governmental Organization
PSM	Propensity Score Matching
RPL	Random Parameter Logit
RTEP	Root and Tuber Expansion Programme
SNEP	Strategic National Energy Plan
TLU	Tropical Livestock Unit
UN DESA	United Nations Department of Economics and Social Affairs
WTA	Willingness to Accept
WTP	Willingness to Pay
ZMK	Zambia Kwacha

CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

1.1.1. Fossil fuels and bioenergy in Africa

Energy services have the potential to boost social and economic welfare of people. Access to energy is a crucial component of poverty alleviation, improving human welfare, and raising living standards (UN DESA, 2005). In the whole world, most energy generation comes from non-renewable sources (oil, coal and gas) though renewable energy sources account for only 13% of the total energy supply (IEA, 2014). It is estimated that the energy consumption of the whole world will increase by 50% between 2005 and 2030. According to EIA (2007), in developing countries, energy consumption is expected to increase from 46% to 58% by the year 2030.

Most countries in Sub-Saharan Africa, rely on traditional biomass (crude oil, natural gas and coal) as the primary energy source and imported fossil fuels (IEA, 2014). In the region, nearly 730 million people live in rural areas where they rely on traditional biomass for cooking (IEA, 2014). In sub-Saharan Africa, energy demand grew by around 45% between 2000 and 2012. In Africa, over 80% of electricity generated is from fossil fuels; but about 620 million people do not have access to electricity (IEA, 2014). Energy demand is predicted to double from 500 million tonnes oil equivalent (Mtoe[1]) in the year 2000 to 1 000 Mtoe in 2030 (Denruyter et al., 2010).

[1]Million tonne of oil equivalent

The heavy reliance on fossil fuels raises serious environmental issues such as depletion of non-renewable resources, Ozone depletion and global warming. According to IPCC (2007), global GHG emissions should be reduced by 50-80% by 2050 to slow down global warming. This means that the use of fossil fuels for energy generation should be restrained. Even though Africa's GHG emissions accounts for less than 4% of the global GHG emissions, the continent is the most vulnerable to climate change effects such as droughts and flooding (World Bank, 2009). This is because Africa is exposed to climate risks such as extreme droughts, flooding and storms. In addition, its low adaptive capacity worsens the situation because the continent is characterized by high rates of poverty, financial and technological constraints and heavy reliance on rain-fed agriculture.

Two types of biomass can be distinguished: traditional biomass and modern biomass. Traditional biomass includes fuelwood, animal waste and traditional charcoal. Modern biomass is biomass produced in a sustainable manner (Sharma, 2005). Traditional biomass such as fuelwood are not included in modern biomass though electricity generation, heat production, transportation fuels are included (Goldemberg & Coelho, 2013).

According to FAO (2004) bioenergy is all energy derived from biofuels, which are fuels derived from biomass (organic matter derived from plants or animals). Biofuels can be solid (charcoal, biochar), liquid (bioethanol, biodiesel, biobutanol, biomethanol) or gaseous (biogas) fuels. Bioenergy potentially offers many advantages to developing countries (FAO, 2010; Osseweijer et al., 2015). Firstly, through carbon sequestration and reduction of CO_2 emissions, bioenergy can contribute in meeting climate change commitments. Secondly, bioenergy can contribute to rural development in creating new jobs, increasing livelihood and market opportunities. This could raise agricultural incomes in rural areas, reduce poverty and accelerate economic growth. Thirdly, bioenergy can contribute to energy security and access through production at the local level, processing, and technological development. Lastly, bioenergy can help in diversifying revenue sources from the agricultural sector, increasing rural income and reducing supply risks. This can contribute to decrease price volatility.

Two types of bioenergy can be distinguished. There are: The first and second generation of bioenergy. The first generation (conventional) is made from the sugars, starchs and vegetable oils from food crops. It is produced through the use of conventional technology (Acosta et al., 2016). The second generation (advanced) are made from biomass wastes or residues and ligneous plants such as trees and shrubs (Acosta et al., 2016). A third generation can be distinguished (Brittaine & Lutaladio, 2010).The third generation as well as the second use advanced conversion technologies. The third generation use algae as feedstock to produce biofuel in order to convert them onto oils.

In Sub-Saharan Africa, drivers of bioenergy expansion especially biofuels have been economic development and energy security, the former being dominant (Gasparatos et al., 2015). The European Union-Renewable Directive (EU-RED) suggested that, in cases where production within the EU was not sufficient, biofuel imports could contribute to meeting the EU biofuel blending mandates (European Union, 2009). In 2009, the European Commission has set a mandatory target of a 20 % share of energy from renewable sources in overall community energy consumption by 2020. The commission has also set a 10 % minimum target to be achieved by its country members for the share of biofuels in transport by 2020. By 2014, the EU realized a 16% share of energy from renewable sources with nine member states who have achieved the 20% target (European Commission, 2017). In 2014, Europe reached 5.7% renewable energy in transport. Achieving the 10% is challenging but feasible (European Commission, 2015). This signal contributed to the fact that investors perceived biofuels as profitable products likely to be channelled to the emerging EU biofuel market (Gasparatos et al., 2015).

1.1.2. Energy consumption in Ghana

Ghana is well known for its land based natural resources such as gold, timber, cocoa, oil palm, and shea (PwC, 2015). In 2012, the agricultural sector accounted for 23% of the GDP (FAO, 2015); in 2015 it accounted for approximately 20% (ISSER, 2016). Ghana's GDP growth has decreased from 7.3% in 2013 to 4.2% in 2014 mainly due to issues related to energy supply and inputs costs (Bayor & Yelyang, 2015).

In Ghana, biomass is the dominant source of energy supply; the country depends entirely on imports in order to meet oil requirements. The production of oil started with a capacity of 85,000 barrels of crude oil per day in the Jubilee field (Abdulai, 2013). In 2007, biomass energy consumption (woodfuel and charcoal) was about 11.7 million tonnes (Ministry of Energy, 2010). It is used mainly for cooking, employing traditional inefficient technologies. Less than 10% of people use modern cooking fuels (improved stoves, kerosene or liquefied petroleum gas) in the country (Ahiataku-Togobo & Ofosu-Ahenkorah, 2009). In 2007, petroleum products and electricity consumption accounted for 1.955 million tonnes and 6,269 GWh respectively (Ministry of Energy, 2010). Biomass (fuelwood and charcoal) consumption in Ghana accounted for 64% of energy consumption. Petroleum products and electricity accounted for 27% and 9% respectively

(Duku, Gu, & Hagan, 2011). However, according to IPCC (2007), combustion of fossil fuels contributes to global warming.

1.1.3. Bioenergy policy development in Ghana

In Africa, the growing interest for biofuel production is due to concerns related to energy security and economic development (Gasparatos et al., 2012). This interest for biofuel production in Africa from foreign investors has sometimes dealt with countries without biofuel policies. Compared to other continents, Africa has not yet adopted a regional policy on bioenergy to regulate the growing industry. However, individually some countries in Africa have emerged with their own bioenergy policy. In Africa, the first country to come out with a formal biofuel policy in 2007 was South Africa, following by Mozambique in 2009 and Angola in 2010 (Gasparatos et al., 2012).

In Ghana, three key documents have been developed in order to promote the use of bioenergy. These documents are: the Strategic National Energy Plan (SNEP) of 2006, the draft Bioenergy Policy of 2010 and the Renewable Energy Act 832 of 2011. The Strategic National Energy Plan (SNEP) of 2006-2020 focuses on three parts, namely the petroleum, the electricity and traditional wood fuels and renewables sectors. Targeting the traditional wood fuels and renewable sectors, five years later after SNEP, a draft Bioenergy Policy was submitted to the Parliament for approval. Later on came the Renewable Energy Act, 832 in 2011.

As stated in the energy sector policy, the Ghanaian government aims to modernize and maximize the bioenergy benefits on a sustainable basis (Energy Commission, 2010). The government targets the use of 10% renewable fuels in the electric and transport sectors by

2020. In 2006, the government of Ghana shared the Strategic National Energy Plan as a response to both international and national energy needs. The Strategic National Energy Plan aims at 10% biofuel share of total fuel content by 2015 in Ghana (Energy Commission, 2006). However, since 2006, no progress report has been published to show how the country is moving towards this goal by the target date. Through its Bioenergy Policy, Ghana seeks to firstly substitute national petroleum fuels consumption with biofuel by 10% by 2020 and 20% by 2030. Secondly, Ghana seeks to remove institutional barriers in order to promote private sector participation in the biofuel industry; thirdly, to create favourable regulatory climate to ensure development of a competitive market, favourable pricing regime and high quality products; improve the efficiency of production technologies and techniques of biofuel with the aim of reducing costs and also raising the quality and efficacy of the product through prioritized research and development programmes; in the medium to long term, become a net-exporter of biofuel and to reduce carbon dioxide emission.(Energy Commission, 2010). This policy has partly been a driving factor for the growing interest in biofuel in the country (Kidido & Kuusaana, 2014). However, to date there is no update on how the country is moving towards the biofuel policy objectives stated above However, the national consumption of petroleum products has risen from 63.5 thousand barrels per day in 2009 to 67 thousand barrels per day by half of the year 2013 (International Energy Statistics, 2015). This suggests the failure of one of the biofuel's policies. In Ghana, the government has shown interest in the development of Jatropha based biofuel (Energy Commission, 2010).

1.2. Problem Statement

The energy sector faces some challenges in Ghana (Energy Commission, 2006). These are related to the increase in energy demand, potential imbalance between national energy production and indigenous sources of supply; inadequate investments in the energy sector, over reliance on fuel imports and wood fuels. According to Amoako-Tuffour & Asamoah (2015), Ghana is experiencing energy gap because: The country depends on one source of electricity generation (hydro) and a poor supply mix; of a weak governance and regulatory mechanisms of the energy sector; Financial losses due to years of under-pricing of energy; Incomplete collections, Inadequate financing of major producers and upgrading of the power sector infrastructure, Inadequate energy efficiency improvement initiatives and dearth of conservation measures; Lack of blueprint in addition to the dearth of long-term and sustainable planning in the energy sector. In order to address the issues of imbalance, low investments and overreliance, Jatropha has been promoted as a panacea and promising feedstock for biofuels.

According to Brittaine & Lutaladio (2010), Ghana was predicted to be among the largest Jatropha producers in Africa by 2015. Projects related to Jatropha development started from 2005; by 2006 there were seventeen biofuel projects in Ghana (Schoneveld, German, & Nutakor, 2010). Several foreign companies (Agroils, Kimminic Estates, Jatropha Africa, Viram Plantation Limited, etc. acquired large tracks of land to produce both edible and non-edible crops for ethanol and biodiesel production for exports (Dogbevi, 2009). Large scale Jatropha (on farms of 100 hectares or more) development was highly criticized by Ghanaian NGOs for issues such land grabbing and food insecurity. Nowadays, mainly participatory and small scale Jatropha developments are going on in Ghana.

Small to medium scale Jatropha production (on farms of 1-99 hectares) provides a promising livelihood diversification option for poor people in rural areas and a way to meet energy demands (Palliere & Fauveaud, 2009), rehabilitate degraded lands (Garg, Karlberg, Wani, & Berndes, 2011) and generate income (Dyer, Stringer, & Dougill, 2012) rather than large scale biofuel plantations (Acheampong & Campion, 2014). In fact, income constitutes a key determinant of food security for poor people in rural areas since adequate income can help them affording appropriate food for their nutritional needs (Faaij, 2008; FAO, 2010). Jatropha can provide new income sources for farmers through Jatropha generated activities such as seeds selling. This supplementary income from Jatropha can impact the food security status of farmers helping them to afford food.

Unfortunately, evidence from numerous bioenergy projects undertaken across Africa to generate biodiesel from Jatropha have failed (Sielhorst, Molenaar, & Offermans, 2008). Currently, in Ghana a market for Jatropha does not exist in all Districts. Jatropha farmers in Mion District are however currently selling Jatropha seeds to a NGO (New Energy). Previously, some farmers were selling the seeds to foreign investors under contract farming. Contract farming is usually considered a substitute for poorly functioning or absent markets such as Jatropha market. In addition, the potential means to induce farmers to grow biomass crops is by offering production contracts. Jatropha contract farming between buyers and smallholder farmers is characterized by a poor negotiating position, locked into unfair contract for smallholder farmers (Beall, 2012); abandoning of contracts without farmers' prior notice (Ariza-Montobbio & Lele, 2010; German, Schoneveld, & Pacheco, 2011). In Ghana, informal contracts are common (Al-Hassan, Sarpong, & Mensah-bonsu, 2006; Dannson et al., 2004). Traders and farmers interact mainly through verbal agreement resulting in violation and none enforcement of the contract terms. Regarding these contracts conditions or attributes, farmers' expectations cannot be easily met.

Jatropha cultivation can have a negative influence on food availability in cases where food crops and production inputs are shifted from food production to Jatropha production (Kgathi, Mfundisi, Mmopelwa, & Mosepele, 2012). In Ghana, most especially in Agogo, Ashanti Region, farmers reported that, the land given by the Chief to a Jatropha company was fertile land[2] previously used to grow maize, yam, plantain and cocoa (Acheampong & Campion, 2014). Land allocation for Jatropha remains a challenge for farmers as well as income generation from Jatropha. Following pioneering work in biodiesel production by Onua Amoah, marginal areas suitable for Jatropha cultivation were selected in 53 Districts in the savannah and forest zones in Ghana for the purposes (Boamah, 2014).

According to Brittaine & Lutaladio (2010), Jatropha grows in tropical and sub-tropical regions. Jatropha may also flower any time in the year. Jatropha sheds its leaves during the dry season, with deep roots making its production suitable to semi-arid conditions. Jatropha can survive with a 250 to 300 mm of annual rainfall and at least 600 mm are

[2] According to Loganathan (1987), a fertile land or soil is a soil in which production is high at the start but diminish rapidly later due to exhaustion of the soil reserve of nutrients. In order to continue the high production of the soil, fertilizers containing the nutrients need to be applied frequently to the soil. However, marginal lands are lands not suitable for food production. FAO (2000) defines marginal lands as "lands having limitations which in aggregate are severe for sustained application of a given use due to: Increased inputs to maintain productivity, low fertility, poor drainage, shallowness, salinity, steepness of terrain, unfavourable climatic conditions, difficult market accessibility, small holdings, poor infrastructure, and limited options for diversification. Marginal lands are also typically characterized by low productivity and reduced economic return or by severe limitations for agricultural use. The concept is often interchangeably used with other terms such as unproductive lands, waste lands, under-utilized lands, idle lands, abandoned lands, or degraded lands (FAO, 1976; Lal, 1991).

needed to flower and set fruit. The northern parts of Ghana are semi-arid, with limited forest cover, and low-to-medium climatic production potential. Northern Ghana has only one rainy season from April to September. The annual rainfall in Northern Ghana is about 1,100 mm. This makes the climate and technical requirements of Northern Ghana suitable for Jatropha production.

According to the Government of Ghana (2010), land investments where predominant in Northern Ghana because food insecurity, poverty and illiteracy are highest. In addition, in Northern Ghana, agriculture account for more than 90% of household incomes and employ more than 70% of the labor force in the region. In Northern Ghana, the West Mamprusi and .Districts were selected for this study. These Districts are among the poorest in Ghana; hence issues of innovation, crop diversification or technology adoption for wealth creation which Jatropha promises become pertinent

The key research questions addressed in this study are:

1. What are the factors explaining farmers' adoption and land allocation to Jatropha in Northern Ghana?
2. What are the factors explaining farmers' decisions to adopt Jatropha either on fertile or marginal lands in Northern Ghana?
3. What is the impact of Jatropha cultivation on farmers' crop incomes in Northern Ghana? and
4. What contract attributes do farmers prefer for Jatropha cultivation in Northern Ghana?

1.3. Objectives of the Study

The major objective of the study is to assess how Jatropha adoption influences the level of crop incomes of farmers and their preferences for production contracts in Northern Ghana.

The specific objectives of the study are as follows: To

1. Identify the factors explaining farmers' adoption and land allocation to Jatropha in Northern Ghana.
2. Identify the factors explaining farmers' decisions to adopt Jatropha either on fertile or marginal lands in Northern Ghana.
3. Measure the impact of Jatropha cultivation on farmers' crop incomes in Northern Ghana and
4. Identify farmers' preferences for contracts attributes in Jatropha cultivation in Northern Ghana.

1.4. Relevance of the Study

This study contributes to the current debates concerning food versus fuel production, use of fertile versus marginal lands for bioenergy crops cultivation in developing countries and agricultural diversification for rural development. Qualitative research methodologies are more common than quantitative ones in the analysis of impact of first generation bioenergy production on livelihoods in developing countries. Empirical studies investigating the impact of bioenergy projects on livelihoods are scarce (Hodbod & Tomei, 2013). This study fills that gap in using the Propensity Score Matching method in order to assess the impact of Jatropha cultivation on farmers' crop incomes.

The study also contributes to the empirical literature using discrete choice experiments in order to inform bioenergy policy design in developing countries. The results from the discrete choice experiment can contribute to increased adoption rates of Jatropha for bioenergy production enabling a more sustainable energy transition: if found to have a positive impact Indeed, knowing which contract attributes farmers prefer for Jatropha contract can increase Jatropha adoption rates if appropriate contracts are designed taking into consideration what farmers want. The study also contributes to the knowledge of designing and tailoring contractual arrangements between potential biofuel investors and farmers for bioenergy crops production. Biofuel investors will gain critical information concerning farmers' view on Jatropha production contracts.

Although similar studies (Paulrud & Laitila, 2010) have assumed homogeneity of preferences related to contract design attributes for farmers, this study allows for heterogeneity of preferences. Farmers do not face the same opportunity cost while accepting a specific contract. Failure to not considering preference heterogeneity could lead to bias results. Additionally, the study incorporates both experiment-based subjective risk perception and risk preference data in the analysis since they can influence an individual's decision under risk.

Concerning Jatropha adoption decision, the study provides a land-specific analysis. The study takes into account the role of land type (fertile versus marginal) in Jatropha adoption process. The study highlights the different factors influencing Jatropha adoption on each type of land. The importance of the study's results on farmer and farm specific factors as well as marketing and income generation and implications for policy refining cannot be over-emphasised.

1.5. Organization of the Report

The thesis report is organized as follows: Chapter One provides a general introduction of the research. It incorporated a background, the problem statement, the research questions, the objectives and the relevance of the thesis. Chapter Two reviews the literature around the topic. Chapter Three reports the different methods used in by the current research as well as information on collected data, sampling method and area of study. The results of this research are presented per specific objectives in Chapter Four. Chapter Five provides the summary, conclusions and policy recommendations of the research.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

Chapter two provides the state of the Jatropha industry in Ghana and both theoretical and empirical literature review on new technologies' adoption. This chapter also provides a literature review of relevant impact evaluation studies highlighting the diverse methods used for impact evaluation. This chapter ends with a literature review of stated preference elicitation approaches, econometric models used to analyze stated preferences and relevant empirical studies.

2.2. Jatropha Industry in Ghana

2.2.1. General description of Jatropha

Jatropha (*Jatropha curcas*) is a tree of up to 5 m in height belonging to the euphorbiaceae family. Jatropha grows well with more than 600 mm of rainfall per year. Its productive lifespan can be around 50 years. It found its originate from Central America. Jatropha is a drought-resistant bush or small tree with spreading branches. It has a smooth grey bark, which gives out a whitish watery latex when cut. Its shrub has a large green to pale-green lobed leaves with a length of about 6 to 15 cm, 5 to 7 shallow lobes (Garg, Khatri, & Gandhi, 2011). Its leaves are positioned alternately, with petiole length of about 6mm to 23 mm. When propagated from seed five (5) roots are formed, one taproot and four lateral roots (Henning, 2003).

Jatropha is a perennial bioenergy and non-staple food crop known for its many advantages such as its adaptability to semi-arid lands requiring low nutrients and care (Brittaine & Lutaladio, 2010; Tomomatsu & Swallow, 2007); its high oil contents and various utilization ways (Kim, 2009); its possibility to grow on degraded and marginal lands (Brittaine & Lutaladio, 2010; Elbehri, Segerstedt, & Liu, 2013; Sulle & Nelson, 2009; Teman, 2010); its oil used to directly power diesel engines, provide electricity and heat for cooking purposes; its storage property; its by-products are used as fertilizer and biogas feedstock and its capacity of rehabilitating degraded lands (Brittaine & Lutaladio, 2010; Garg et al., 2011). The income generation from Jatropha is possible through the use of its oil to produce soap (Brittaine & Lutaladio, 2010; German et al., 2011).This allows households to purchase basic, but highly valued, household goods (German et al., 2011).

2.2.2. Jatropha: a risky crop for farmers?

The economic and agronomic characteristics of perennial bioenergy crops such as Jatropha make them risky choices (Skevas, Swinton, Tanner, & Sanford, 2016). First of all, investment in such crops is characterized by high establishment cost, establishment problems such as extreme climatic and pest events (Skevas et al., 2016; Thinggaard, 1997; Yang, Paulson, & Khanna, 2014), price and yield risks (Khanna, Louviere, & Yang, 2016). Secondly, taking Jatropha as an example, its productive lifespan can be around 50 years. The crop takes more than three years to start producing seeds (Mponela, Jumbe, & Mwase, 2011; Pradhan, Naik, Bhatnagar, & Vijay, 2010). The harvest is done around 3 months after flowering when the seeds become mature (color changes from green to yellow-brown). There is no income for farmers until the seeds reach maturity. Thirdly, the removal cost of perennial crops in order to make land available for another crop is high. Finally and not the least markets exist for majority of crops that farmers grow decreasing then uncertainty and risk (Epplin, Clark, Roberts, & Hwang, 2007). The absence of markets for bioenergy crops aggravates the perceived risks for farmers. Farmers see Jatropha production as risky and uncertain (Goswami & Choudhury, 2015).

2.2.3. History of Jatropha cultivation in Ghana

Jatropha industry started in Ghana without any biofuel policies (Campion, Essel, & Acheampong, 2012). In Ghana, prior to its introduction as a bioenergy crop, Jatropha was traditionally grown as gardens and a hedge or fence plant around homes in order to protect houses and fields against domestic animals and sun exposure (Acheampong & Betey, 2013). Jatropha was then grown for the above purposes but not for oil production. Ghana got interested in Jatropha cultivation mainly for its ability of growing on marginal lands. Jatropha was then considered for its ability to generate energy without compromising food security (Boamah, 2014).

In 2003, Onua Amoah, Chief Executive Officer of Anuanom Industries Ltd, a biodiesel processing company was the pioneer of Jatropha development mainly to produce biodiesel in Ghana (Brew-Hammond, 2009). Later on, he asked for government support for Jatropha development and market creation (Boamah, 2014). He also succeeded in processing Jatropha seeds into biodiesel. Based on this success, in 2005, a biofuel committee was created to elaborate a Biofuel Policy for Ghana (Brew-Hammond, 2009).

In 2006, the Government of Ghana created the National Jatropha Project Planning Committee and sponsored Jatropha trainings and workshops under the supervision of the Ministry of Food and Agriculture and the Ministry of Local Government and Rural Development (Boamah, 2014). Following these meetings, marginal areas suitable for Jatropha cultivation were selected in 53 Districts in the savannah and forest zones in Ghana (Boamah, 2014).

In 2007, further to oil and gas discoveries, the government lost interest in Jatropha and welcomed interested foreign investors. Due to international euphoria for biofuels, Ghana welcomed an inflow of foreign biofuel projects from Norway, Italy, Canada and Japan (Boamah, 2014). However, the bioenergy policies namely the Draft Biofuels Policy (2005), Renewable Energy Act (2011) and Draft Bioenergy policy (2011) fail to fix issues related to land acquisition, markets and government incentives (Boamah, 2014). Large scale land acquisitions for Jatropha raised concerns related to land loss, degradation and food insecurity by NGOs and the media. Later on, the government removed its support for large scale Jatropha plantations leading to the failure of these projects. Nowadays, small scale Jatropha projects are dominant in Ghana (Boamah, 2014). Table 2.1 shows biofuels investment in Ghana.

Table 2.1: Biofuels land acquisition and use in Ghana

Region in Ghana	Company	Country of origin	Location in Ghana	Year established	Size of land acquired (ha)	Area planted (ha)	Feedstock
Brong Ahafo	Savannah Black Farming & Farm Management Limited	United States	Ahinakom	2006	202	121	Jatropha
	Agroils	Italy	Yeji		15,000	175	Jatropha
	Smart Oil	Italy	Yeji	2009			
	Kimminic Estates	Canada	Abease	N/A	15,000	850	Jatropha
			Dinkra	2007			Jatropha
			Bredie	2007			Jatropha
			Atebubu	N/A	30,000	2,000	Jatropha
			Yeji (Kobre)	2010	N/A	450	Jatropha
	N/A	N/A	Prang	2008	N/A	520	Sugarcane
	Jatropha Africa	U.K.	Domeabra	2007	50,000	1,050	Jatropha
	N/A	N/A	Kwanim	N/A	22,000	1,210	Maize/Soybean
	Jatropha Africa	U.K.	Kadelso	2007	50,000	202	Jatropha
	Natural African Diesel Ghana Limited	Ghana	Yeji	2008	50,000	1,000	Jatropha
	N/A		Dinkra	2007	400	200	Jatropha
	N/A		Bredie	2007	12,140	6,070	Jatropha
Central Region	Buabeng Oil Palm Plantation	Ghana	Dunkwa on Offin	2011	N/A	8,230	Palm Oil
	Symboil AG	Germany	Weniba	2007	7,000	N/A	Jatropha
Eastern Region	Ghana Oil Palm Development Company	Ghana	Kwae	N/A	35,235	15,075	Palm Oil
	Viram Plantation Ltd.	India	Afram plains	2007	400,000	60,030	Palm Oil/Sugarcane
	Anuanom Farms	Ghana	Juapong	2006	405	200	Jatropha
Northern Region	BioFuel Africa	Norway	Yendi	2007	40,500	15,000	Jatropha
			Alipe	2007	38,000	0	Jatropha
			Kpachaa	2007	10,696	1,000	Jatropha
	N/A	N/A	Makango	2008	28,350	13,000	Jatropha
	Northern Sugar Resource	Brazil	Kpembi	2009	N/A	N/A	Sugarcane
	Integrated Tamale Fruit Company		Dipale, Gushie and Tunayilli	2001	1,363	600	Jatropha
Volta Region	Galten Agro Ltd	Israel	Adidome	2008	100,000	325	Jatropha
	BioFuel Africa	Norway	Lolito	2006	2,300	N/A	Jatropha

Source: Compiled from Ahmed, Campion, & Gasparatos (2017)

2.3. Adoption of New Technologies

2.3.1. Concept of adoption

Adoption is defined in diverse ways. For Feder, Just, & Zilberman (1985), adoption is the degree or extent of use of a new technology. The adoption process involves the choice of the resource (land and labor) and quantity that is to be allocated to the new technology in case the technology is not divisible (mechanization, irrigation). However, in case of a divisible technology, the decision process involves area allocations and level of use (Feder et al., 1985). Consequently, the adoption decision process is made of a simultaneous choice of adopting or not and the intensity of use of the new technology.

According to Rogers (1983), adoption is the use or nonuse of a new technology by a farmer at a given period of time. He distinguished five types of adopters: innovators, early adopters, early majority, late majority, and laggards. Innovators are usually the first adopters of the new technology. They are: Willing to take risks, younger in age, from highest social class, having good financial situation and closest to other innovators. The financial resources they have help them in absorbing any failures they might face. Early adopters are expected to be risk taker, younger, venturesome and educated. However, late adopters are risk averse, older, less educated and conservative. Early majority have highest degree of opinion leadership. Their opinion is most of times respected by other villagers. They are discriminating and judicious in making decisions about innovation. Laggards adopt but later discontinue due to disenchantment. The categorization of adopters is useful in case there is evidence indicating a movement from one category to the other, depending on the technology introduced.

Also Rogers (2003) defines adoption as the decision of full use of an innovation as the best course of action is available. Adoption is a decision-making process, in which an individual goes through a number of mental stages before making a final decision to adopt an innovation.

2.3.2. Theories explaining adoption of new technologies

In developing countries, three theories explain farm household production choices (Mendola, 2007), There are: Profit maximization, utility maximization and risk aversion.

- **Profit maximization theoretical framework**

Schultz (1964) hypothesized farm households in developing countries as "poor but efficient". This means that poor households do the best they can under the difficult circumstances life has placed them in. They are efficient in allocating their resources and respond to price incentives. Farm households are seen as profit maximizers in a perfectly competitive market. Bliss & Stern (1982) have empirically questioned this theory and found a contradictory result in India. They showed that farmers in Palandur, India were not doing the best that they could do given their resources. They concluded that farmers are not efficient and profit maximizers as Schultz (1964) suggested. They concluded that farm households making trade-offs between profit and other household goals cannot be typically categorized as profit maximizers.

- **Utility maximization theory**

Utility maximization theory considers farm households as both families and firms. They are both consumers and producers. In the absence of labor market and unlimited land supply, Chayanov (1966) demonstrated the influence of household size and structure on farmer behavior. Chayanov (1966) showed that the amount of land cultivated depends on the ratio of consumers to workers within the farm household. In the early stages of the household's life cycle, a small acreage of land is cultivated due to the small age of the children. As time goes, the children grow in age, become economically active and enter the family labor force, the amount of cultivated land expands. In Chayanov's model, peasant families operate the land with the labour of family members alone. Households can accommodate more working members by renting or buying more land. They have relatively free access to land. He concluded that farm households do not always maximize production or profit by producing as much as possible but rather seek to maximize utility with a trade-off between household consumption and leisure. In the context of Ghana, Chayanov theory is very limited in the sense that household labor can be shared or hired especially for weeding and harvesting. Access to family labour can be difficult due to the growing strength of education and rural urban migration. In Ghana, 44.3% of the currently employed population work as skilled agricultural and/or fishery worker (Ghana Statistical Service, 2014c). In Ghana, 18% of land is owned by the State, 80% by traditional rulers and 2% by both (Bugri & Yeboah, 2017). Access to land depends on land tenure agreement. The co-existence of these systems of law regulating land leads to some difficulties, especially for women and the rural and urban poor. Under the customary land administration system, land access in Ghana tends to favour use and ownership by men, especially when it comes to inheritance (Kotey & Tsikata, 1998). However, under the customary land administration, a non-member of the community can access land through purchasing, renting, gifting, licensing or sharing contractual arrangements. Under the statutory land administration system, legal procedures are most of the times complex. In addition, the procedure is costly. Considering the high rate of illiteracy in rural areas, lack of money, access to land under the statutory land administration is very limited.. The model of Chayanov was criticized for its assumption of missing labor market and unlimited land supply.

According to Becker (1965), farm households maximize utility through consumption of available goods subject to full income constraint. In case where market is perfect, production and consumption decisions are considered as separable. According to I. Singh, Squire, & Strauss (1986), the main reasons of that separability are: exogenous price, independent leisure and labour-time, household labor allocation determined by market wage and income representing the only link between consumption and production of the farm households. However, in case of imperfect markets for either output or input, farm decisions are non-recursive. The reason is that the household decides on time allocation related to production, affecting then consumption of leisure (I. Singh et al., 1986).

Profit maximization and maximization of utility theories fail to include risk and uncertainty in farm household decisions process

- **The risk averse farm household**

Mendola (2007) conceptualized farm households' risk aversion through two theories: expected utility and disaster-avoidance theories. From the expected utility theory perspective, a farm household chooses among risky alternatives mainly based on their preferences related to the possible outcome and the probability of occurrence of that outcome. This theory pictures farm households as utility maximizers constrained by risks.

However, from the disaster-avoidance theory, a farm household who faces risky income sources will first isolate safe alternatives and from the safe alternatives, chooses based on expected utility (Mendola, 2007). In this case, the decision-maker wants to avoid the risk that his/her income falls below the subsistence level. Based on this criterion, a farm household could prefer risky income sources or low risk activities. This means that at low levels of income, farm households do not behave according to expected utility theory.

The utility maximization theory is used in the report.

2.3.3. Empirical studies on factors influencing adoption of bioenergy crops

Bioenergy crops cultivation as non-traditional land use or new crop variety could be considered as innovation (Villamil, Silvis, Anne, & Bollero, 2008). The literature identified factors that affect the adoption of a new technology in general and a perennial bioenergy crop in particular. Although, specific literature concerning dedicated bioenergy crops adoption is still scarce, some socioeconomic and demographic characteristics are expected to be in line with the new technology adoption literature. In addition, different methods of analysis have been used to study adoption of bioenergy crop.

- **Methods of analysis**

Several methods have been used in the literature to study the determinants of bioenergy crops adoption among farmers. Paulrud & Laitila (2010) examined Swedish farmers' willingness to produce energy crops using discrete choice experiment. Goswami & Choudhury (2015) used a Probit model to firstly analyze farmers' decisions to adopt

Jatropha and secondly to continue with Jatropha cultivation. Hoque, Artz, Jarboe, & Martens (2015) estimated a Probit model to analyze factors that determine biomass production participation. They also used a multivariate Probit model to estimate these factors by biomass type. Jensen et al. (2007) employed a Tobit model to assess willingness to produce switchgrass by farmers. Roos, Rosenqvist, Ling, & Hektor (2000) used a Tobit model to study factors influencing short-rotation willow coppice adoption by Swedish farmers. Maonga, Maganga, & Kankwamba (2015) also used a Probit model to analyze smallholder farmers' decisions to incorporate Jatropha in their cropping systems in Malawi. Mponela, Jumbe, & Mwase (2011) studied factors affecting land allocation to Jatropha and its extent in unproductive lands by farmers in Malawi using Logit and Tobit models respectively. Gedikoglu (2015) used an ordered Probit model to analyze the socio-economic factors affecting willingness to produce switchgrass and miscanthus in Missouri and Iowa by farmers. Giannoccaro, Barbuto, Baselice, & Falcone (2014) used a Probit model to analyze farmers' decisions to adopt energy crops in Spain. Qualls et al. (2012) studied factors influencing farmers' willingness to produce and devote a share of their farmland to switchgrass in the southeastern United States using a Tobit model. Breen, Clancy, Moran, & Thorne (2009) used a Probit model to analyze factors influencing farmers' willingness to adopt energy crops in Ireland. Caldas et al. (2014) studied factors affecting farmers' willingness to grow biofuel feedstocks in Kansas. They used a Logit model and derive the marginal effects. Cheteni, Mushunje, & Taruvinga (2014) used a Heckman two-step model to identify barriers and incentives influencing biofuels crops adoption by smallholder farmers in South Africa. Bocquého, Jacquet, & Reynaud (2015) studied the determinants of miscanthus adoption among

French farmers using a two part (hurdle) model. They also used a bivariate Probit to study adoption of miscanthus depending on whether the farmer grows miscanthus on fertile or marginal lands.

Numerous studies have used different models such as Logit, Probit and Tobit to analyze factors affecting farmers' decision to grow bioenergy crop or not and its extent. Probit and Logit models are more appropriate based on the dichotomous nature of the dependent binary choice (to adopt or not). However, these models cannot measure the extent of adoption (Feder et al., 1985). The Tobit model is applicable for analyzing extent of adoption because the dependent variable (number of hectares to allocate to Jatropha) has censored distribution. The number of hectares to allocate to Jatropha is equal to zero for those not growing it. The Tobit model assumes that the decisions to grow Jatropha and its extent are made simultaneously and related.

Usually data about adoption and its extent lead to many zero responses. Several models can deal with binary choices. However, the choice of the good specification lies in the source of the zero responses (Bocquého et al., 2015). In the literature, Tobit model is widely used as a corner solution (Jensen et al., 2007; Mponela et al., 2011; Qualls et al., 2012; Roos et al., 2000). However, Tobit models restrict that the explanatory variables and the coefficients to be the same for the two decision processes (decision to adopt or not and its extent) (Dong & Saha, 1998). However, there might be two decisions defining adoption models. The first decision is the decision to adopt or not. The second decision is the decision concerning the extent of adoption. Double hurdle models are more flexible by allowing distinct and independent mechanisms to explain the two decision processes (participation and intensity decisions) (Cragg, 1971). In addition, explanatory variables may be different across the two decisions.

- **Factors influencing bioenergy crop adoption and the extent of adoption**

According to Feder, Just, & Zilberman (1985), the effect of farm size on adoption of a new technology depends on: the fixed costs inherent in the new technology adoption, risk preferences, credit access, labour, etc. Small farms characterized with large fixed costs are less prone to technology adoption. Some empirical studies on energy crops adoption such as Bocquého, Jacquet, & Reynaud (2015); Breen, Clancy, Moran, & Thorne (2009); Clancy, Breen, Moran, Thorne, & Wallace (2011); Lynes, Bergtold, Williams, & Fewell (2012); Negash (2015); Rämö, Järvinen, Latvala, Toivonen, & Silvennoinen (2009); Roos, Rosenqvist, Ling, & Hektor (2000) confirmed that farm size has a positive influence on adoption of bioenergy crops. However, Jensen et al. (2007); Paulrud & Laitila (2010) found that farm size negative influences technology adoption. Lynes et al. (2012) also found that farm size has no influence on perennial bioenergy crop adoption.

Age of the farmer represents its innovativeness, making younger farmers more innovative than older farmers. Younger farmers are assumed to have more years ahead to receive returns from their investment in the new technology, making them more prone to innovation. Older farmers are expected to have gained more experience making them less prone to adopt a new technology. The literature shows two possible relationships between age and adoption of new technology. Breen et al. (2009) studying farmers' willingness to adopt energy crops in Ireland. They found that age has a negative influence on farmers' willingness to adopt energy crops. Bocquého et al. (2015);

Gedikoglu (2015); Jensen et al. (2007); Paulrud & Laitila (2010); Rämö et al. (2009) confirmed the negative relationship between age and bioenergy crops adoption. Roos et al. (2000) also found a negative relationship between age and adoption of Short-rotation Willow Coppice for farmers less than 35 years in Sweden. Giannoccaro, Barbuto, Baselice, & Falcone (2014) found a negative influence between farmers older than 66 years and adoption of energy crops in Spain. However, Mponela et al. (2011) confirmed that age has a positive relationship on adoption of Jatropha on unproductive lands in Malawi. Roos et al. (2000) found a positive relationship between age and adoption of Short-rotation Willow Coppice for farmers between 50–65 years. Other studies found that age is not significant in explaining adoption of bioenergy crops (Breen et al., 2009; Clancy et al., 2011; Goswami & Choudhury, 2015; Lynes et al., 2012; Maonga et al., 2015; Negash, 2015).

Education is assumed to equip farmers with good skills helping them to acquire information (technology) and easily apply it. Majority of empirical studies confirmed a positive relationship between education and energy crops adoption (Giannoccaro et al., 2014; Jensen et al., 2007; Maonga et al., 2015; Mponela et al., 2011). However, some studies found that the level of education of farmers has no significant influence on adoption of bioenergy crops (Clancy et al., 2011; Goswami & Choudhury, 2015; Hoque et al., 2015).

Jensen et al. (2007) found that land leasing has a negative influence on farmers' willingness to convert land to switchgrass production. Other studies (Gedikoglu, 2015; Lynes et al., 2012; Roos et al., 2000) found a positive relationship between leased land and farmers' willingness to produce bioenergy crop. Giannoccaro et al. (2014) found a positive influence between land size owned and adoption of energy crops in Spain. However, other studies did not find a significant influence of land tenure on bioenergy crop adoption (Bocquého et al., 2015; Breen et al., 2009; Cheteni et al., 2014; Clancy et al., 2011; Paulrud & Laitila, 2010).

Negash (2015) studied the adoption of castor bean as a bioenergy crop and found that women-headed households tend to adopt less. Caldas et al. (2014) also found that being a female farmer reduces the probability of planting perennial bioenergy crop in Kansas. Female headed households may prefer to cultivate food crops instead of cash crops. In addition, men and women face different constraints such as unequal access to land, labour or market information. However, Maonga et al. (2015) found no significant effect of gender on farmers' decisions to adopt Jatropha in Malawi.

Access to extension services has a positive influence on Jatropha adoption in North East India (Goswami & Choudhury, 2015). Indeed farmers are usually informed about the existence as well as the effective use and benefit of new technology through extension services. This can enhance the adoption of the new technology. Some studies found no significant relationship between access to extension services and adoption of bioenergy crops (Breen et al., 2009; Clancy et al., 2011; Gedikoglu, 2015; Maonga et al., 2015; Negash, 2015). In case, the promotion of the bioenergy crop is primarily undertaken by the company which wishes to grow the crop, the insignificance of access to extension services can be expected.

The literature concerning the effect of farmer' engagement in off-farm activities on bioenergy crops adoption is mixed. Some studies found that there is a negative relationship between engagement in off-farm activities and bioenergy crops adoption (Goswami & Choudhury, 2015; Jensen et al., 2007; Mponela et al., 2011; Negash, 2015). Bocquého et al. (2015) found that income from off farm activities positively influences miscanthus adoption in France. Caldas et al. (2014) confirmed a positive relationship between off farm income and energy crop adoption in Kansas, USA. However, Lynes et al. (2012) found that engagement in off-farm activities has no significant effect on willingness to grow perennial bioenergy crop in Kansas, USA.

Maonga et al. (2015) found that distance to market has a negative influence on Jatropha adoption in Malawi. However, Cheteni et al. (2014); Goswami & Choudhury (2015) found that distance to market has no influence on adoption of bioenergy crops .

Farming experience is found to have no influence on Jatropha adoption (Goswami & Choudhury, 2015). Lynes et al. (2012) also found no significant relationship between farming experience and willingness to grow perennial bioenergy crop in Kansas, USA.

Jensen et al. (2007) found that farm income negatively influences farmers' willingness to convert land for switchgrass cultivation in Tennessee.

Livestock ownership has a negative influence on farmers' willingness to convert land to energy crops (Bocquého et al., 2015; Jensen et al., 2007; Mponela et al., 2011). Mponela et al. (2011) used the number of livestock units (LU[3]) to capture livestock. Farmers owning livestock might have less land available for bioenergy conversion. In addition, for livestock owners, marginal land is generally productive and is usually either unavailable, or available but more profitable than growing a bioenergy crop. In this case,

[3] 1LU=1.2 cows=5 sheep=4goats

livestock ownership has a negative influence on adoption. Negash (2015) showed that livestock ownership in TLU[4] positively influences castor (bioenergy crop) adoption in Ethiopia. In Negash's study, land holding was a key eligibility criterion to participate in Castor cultivation. Indeed farmers having more land had more livestock. In this case livestock ownership enhances adoption. However, Lynes et al. (2012) found livestock has no significant influence on farmers' willingness to grow a perennial and an annual bioenergy crop. Caldas et al. (2014) also found no significant influence of livestock on perennial bioenergy crop adoption in Kansas, USA.

Membership of Farmer Based Organization (FBO) influences negatively farmers' willingness to convert land to energy crops (Jensen et al., 2007). Giannoccaro et al. (2014); Maonga et al. (2015) found no significant effect of FBO on adoption of energy crops in Spain.

Cheteni et al. (2014) showed that household size has a positive influence on biofuels adoption in South Africa because larger households might be expected to be interested in opportunities that would secure their livelihoods. Negash (2015) also found a positive relationship between household size and castor bean adoption in Ethiopia. Castor bean is a labor intensive crop. In case the household uses family labor, the higher the size of the household, the higher the probability of adoption the crop. However, Maonga et al. (2015) found that household size has no significant effect on Jatropha adoption decisions by farmers in Malawi.

[4] cattle = 0.7, sheep = 0.1, goats = 0.1, pigs = 0.2, chicken = 0.01

Lynes et al. (2012) showed that irrigation positively influences land allocation decisions to grow an annual and a perennial bioenergy crop in Kansas (USA). Roos et al. (2000) confirmed a positive relationship between irrigation and short-rotation willow coppice adoption among Swedish farmers. However, Caldas et al. (2014) found no effect of irrigation on annual and perennial bioenergy crops in Kansas, USA.

Goswami & Choudhury (2015) found that risk loving farmers are more prone to adopt Jatropha in India. Lynes et al. (2012) found that risk aversion negatively influences farmers' willingness to produce dedicated annual bioenergy crop in Kansas (USA). However, Ridier, (2012) found that risk averse farmers are more prone to new short rotation coppice adoption in south-western France. Caldas et al. (2014) found a positive influence between being risk averse and adoption of perennial bioenergy crop in Kansas.

- **Measurement of variables used in the studies of adoption of bioenergy crop by farmers**

Several researchers have suggested different ways of measuring the factors that explain adoption of bioenergy crop by farmers (Table 2.2). Some of the measures are dichotomous, categorical or continuous.

Table 2.2: Measurement of explanatory variables used in the studies of adoption of bioenergy crop by farmers

Variables	Measurement	Studies
Age	Age of the farmer (in years)	Bocquého et al. (2015), Breen et al. (2009), Cheteni et al. (2014), Gedikoglu (2015), Giannoccaro et al. (2014), Goswami & Choudhury (2015), Hoque et al. (2015), Jensen et al. (2007), Lynes et al. (2012), Maonga et al. (2015), Mponela et al. (2011), Negash (2015)
Gender	1 if the farmer is a female and 0 if male/ 1=male 0=Female	Caldas et al. (2014), Cheteni et al. (2014), , Maonga et al. (2015), Mponela et al. (2011), Negash (2015)
Education	Education level of the farmer (scale 1-6)	Breen et al. (2009)
	Less than high school (1=Yes, 0= no), High school degree (1=Yes, 0= no), Some college or vocational school (1=Yes, 0= no), Bachelor degree (1=Yes, 0= no), Graduate degree (1=Yes, 0= no)	Gedikoglu (2015),
	Education level of farm head (five levels): 1=None, 2=Primary school, 3=High school, 4=Professional master, 5=Degree/Ph.D.	Giannoccaro et al. (2014)
	1 if the farmer has earned a college degree, 0 otherwise	Caldas et al. (2014), Lynes et al. (2012)
	Number of years of education	Goswami & Choudhury (2015), Maonga et al. (2015), Mponela et al. (2011),
	High School=0, Some college=1, College degree=2	Hoque et al. (2015)
	1= some high school or less, 2=high school graduate, 3=some college, 4=college graduate, 5=post graduate	Jensen et al. (2007)
Household size	Number of people in the household	Maonga et al. (2015), (Cheteni et al., 2014), Negash (2015)
	Number of adults in the household	Mponela et al. (2011),
Off-farm activities	Availability of non-farm employment Opportunity (1=Yes, 0=No)	Goswami & Choudhury (2015)
	1 if any member of the household brings home off-farm income, 0 otherwise	Lynes et al. (2012)

Livestock	Number of animals (in Livestock units)	Gedikoglu (2015), Mponela et al. (2011),
	1=Yes the farmer has livestock, 0=No	Jensen et al. (2007)
Farm Size	Total arable area	Bocquého et al. (2015), Caldas et al. (2014),
	<30 years=0, >30 years =1	Hoque et al. (2015)
	Size of the farm (hectares/Acres)	Breen et al. (2009)
Extension services	Contact with the extension services (1=No, 2=Yes)/ 1=Yes 0=No	Cheteni et al. (2014), Breen et al. (2009), Goswami & Choudhury (2015), Maonga et al. (2015),
	Farmer assisted by an extension service (1=Yes, 0=No)	Giannoccaro et al. (2014),
FBO	Membership of a farmer union (1=Yes, 0=No)	Giannoccaro et al. (2014)
Farming Experience	Number of years the farmer has been farming in years	Caldas et al. (2014), Cheteni et al. (2014), Goswami & Choudhury (2015), Lynes et al. (2012), Lynes et al. (2012)
Access to credit	1= Yes the farmer has access to credit, 0= No	Cheteni et al. (2014),
Size of land owned	Proportion of land out of the arable area which is owned	Bocquého et al. (2015),
	Total land owned	Giannoccaro et al. (2014)
Leased & owned land	1= if the farmer has leased land, 0 Otherwise	Gedikoglu (2015),
	Amount of land which is owned	Breen et al. (2009),
Livestock	1= Has livestock, 0 otherwise	Bocquého et al. (2015)
Marginal land	1=Having some marginal land in the farm, 0 otherwise	Bocquého et al. (2015)
Discount Factor	Parameter for the exponential discount factor	Bocquého et al. (2015)
Risk	1=Risk taker, 0=Risk avoider	Goswami & Choudhury (2015)
	1 if the farmer avoids taking risk, 0 otherwise	Lynes et al. (2012),

Education: Some authors measured education as a categorical or continuous. However it is always better if the data is available to considered education as a continuous variables.

Household size: Considering household as the number of adults instead of the total number of people in the household in the household makes more sense since Jatropha is a labour intensive. Adults are more able to help cultivating the crop than children.

2.4. Impact of Bioenergy Crop Cultivation on Crop Income of Farmers

2.4.1. Review of selected impact evaluation studies

Magrini & Vigani (2014) studied the impact of agricultural technologies (improved seeds and inorganic fertilizers) on food security of maize farmers in Tanzania using a propensity score matching technique. The results showed that adoption of improved seeds and inorganic fertilizers has a positive and significant impact on food security of maize farmers.

Obisesan & Omonona (2013) measured the impact of the Root and Tuber Expansion Programme (RTEP) on food security of cassava households in Nigeria. Using a propensity score matching method, the authors computed the Average Treatment Effect for the Treated to measure impact. The authors found that the food insecurity impact of the RTEP programme of beneficiaries was lower than that of the non-beneficiaries. This suggests that the RTEP has the potential to improve food security.

Gebrehiwot & Veen (2015) studied the impact of a Food Security Package (FSP) programme on households' food consumption in Tigray region, Northern Ethiopia. The FSP programme aims to secure food for poor households by diversifying their income base through provision of credit for specific activities. They employed a propensity score matching approach to estimate the causal effects. Using Kernel matching, they found that the programme improved food calorie intake by 772.19kcal/day per adult equivalent unit.

Shiferaw, Kassie, Jaleta, & Yirga (2014) studied the impact of improved wheat varieties adoption on household food security in Ethiopia. Using endogenous switching regression, adoption of improved wheat increased the probability of food security by 2.7% for adopters and 4.5% for non-adopters had they adopted improved varieties.

Khonje, Manda, Alene, & Kassie (2015) studied the impact of improved maize varieties on welfare in Eastern Zambia. They selected crop incomes, consumption expenditure, and food security as welfare indicators. Using both endogenous switching regression and propensity score matching, they found that adoption of improved maize increased crop income, consumption expenditure, and poverty. The propensity score matching results shows that adoption of improved maize varieties increased crop income per hectare in the range of ZMK[5]2.3 million to ZMK2.4 million (using respectively Nearest Neighbour Matching and Kernel Based Matching). The adoption increased average consumption expenditure per capita in the range of ZMK271,122 to ZMK305,122. The adoption reduces the probability of poverty by 11 percentage points. Using the Endogenous Switching Regression (ESR), the average increment on crop income per hectare for adopters (ATT) is ZMK78,900 and on consumption expenditure per capita is ZMK324,690. Adoption of improved maize varieties reduced the probability of poverty by 21 percentage points for adopters using ESR.

Kassie, Shiferaw, & Muricho (2011) measured the impact of improved groundnut adoption on crop income and poverty in rural Uganda. Using propensity score approach, the authors showed that adoption of improved groundnut varieties increased crop income in the range of US$130-$254 and decreased poverty by 7–9 percentage points.

[5] Zambia Kwacha

Becerril & Abdulai (2009) used a propensity score matching method to measure the impact of improved maize varieties adoption on household income and poverty in Chiapas and Oaxaca regions in Mexico. Using both nearest neighbor and kernel-based matching algorithms, the authors found that adoption of improved varieties increased per capita expenditures and the probability of escaping poverty of farmers.

2.4.2. Methods of impact evaluation

In impact evaluation studies, the outcome of interest is a function of observable and unobservable characteristics of the population and whether or not the population participated in the programme. In order to measure the impact of the programme on the outcome, there is a need to control for all observable and unobservable factors. Failure to control for these factors might lead to bias results. In order to deal with the issue of selection bias, the standard analytical methods of impact evaluation include: Heckman two step and instrumental variables (Kassie et al., 2011).

The Heckman two-step assumes that errors are normally distributed while the Instrumental Variable method depends on the identification of valid instruments. Both methods deal with the problem of self-selection by imposing distributional and functional form assumptions. The imposition concerns a linear functional form of the outcome equation and an extrapolation over regions of no common support, for adopters and non-adopters.

Unlike, the Heckman two-step and Instrumental Variables methods, the Propensity score Matching (PSM) does not impose distributional and functional form assumptions.

Rosenbaum & Rubin (1983) developed the propensity score matching (PSM) method. The main purpose for using matching was to find a group of treated respondents (adopters) similar to the control group (non-adopters) in all relevant pretreatment characteristics, where the only difference was that one group adopted a new technology and other group did not.

The PSM approach requires the satisfaction of two assumptions: the Conditional Independence Assumption (CIA) and the Common Support Condition (CSC) (Rosenbaum & Rubin, 1983). The CIA means that the selection into the treatment or participation group is only based on observable characteristics. In addition, the treatment effect on the outcome variable, that is crop income can be explained by these observable characteristics. The common support condition requires that the Average Treatment Effect for the treated (ATT) is defined within the region of common support ensuring that households with the same observable characteristics have a positive probability of being both treated (adopters) and non-treated (non-adopters) (Heckman, Ichimura, & Todd, 1997). The Propensity Score Matching is a two-step methodology. First, a probability model for adoption of the new technology is estimated in order to get the propensity scores of adoption for each household. Second, in order to estimate the ATT, each household adopter is assigned or matched to a household non-adopter with similar propensity score.

Matching methods exist to match adopters with non-adopters. The common methods used are the Nearest Neighbor Matching (NNM) and the Kernel-Based Matching (KBM) (Becerril & Abdulai, 2009). The Nearest Neighbor Matching method consists of matching adopters with non-adopters having the closest propensity score. The Nearest

Neighbor Matching can be categorized into the Nearest Neighbor Matching with replacement and the Nearest Neighbor Matching without replacement. When there is few comparison units, matching with replacement allows one comparison unit to be matched more than once with each nearest treatment unit. However, matching without replacement forces the matching between the treatment group and the comparison one that are quite different in propensity scores. This enhances the likelihood of bad matches (increase the bias of the estimator). The Kernel-Based Method consists of matching adopters with a weighted average of all non-adopters. Those weights are inversely proportional to the distance between the propensity scores of adopters and non-adopters (Becerril & Abdulai, 2009). In addition, in order to understand how sensitive the results can be, two additional matching procedures are used: Radius matching and stratification matching. The Radius Matching matches only those control and treatment observations within a pre-defined range on the propensity score. The Stratification Matching divides the propensity score into a set of intervals. It also estimates the average treatment effects on the treated within each interval using the mean difference between the control and treated observations. The number of strata is generated from the propensity score by STATA. The current study uses the Nearest Neighbour Matching with replacement to assess the robustness of the results because the non-treatment sample and the treatment sample are equal (200 adopters and 200 non-adopters). The non-treatment sample is quite few compared to the treatment sample.

After matching, the balance test is required in order to compare the before and after matching and verify if there is no differences after conditioning on the propensity score

(Caliendo & Kopeinig, 2008). Among all the existing balancing tests, the mean absolute standardized bias suggested by Rosenbaum & Rubin (1985) is the most used.

2.5. Farmers' Preferences for Contracts to Produce Bioenergy Crops

2.5.1. Concept of contract farming

Authors such as Rehber (1998) and Runsten & Key (1996) traced the principles of contract farming back to the 19th century, when contract was used in the United States for processing crops such as sugar beets and peaches, and in Taiwan, for sugar production under the Japanese colony.

Costales & Catelo (2009) defined contract farming as a binding arrangement between a contractor usually a firm and a contractee usually a producer in the form of a 'forward agreement' where remuneration, obligations and product specifications (quality, quantity,etc.) are determined.

For Da Silva (2005), contract farming is seen as an intermediate mode of coordination, whereby the conditions of transactions are set among partners by legally enforceable and binding agreement. The conditions of transaction cover production technology, price discovery, risk-sharing and other product and transaction attributes.

Minot (2011) defined contract farming as an agricultural production carried out according to a prior agreement in which the farmer commits to producing a given product in a given manner and the buyer commits to purchasing it. Most of the times, the buyer provides technical assistance, seeds, fertilizer, and/or other inputs, and guaranteed price (Eaton & Shepherd, 2001).

Rehber (2007) defined contract farming as a contractual arrangement between farmers and other firms where the arrangement can either be oral or written, conditions of production and marketing of an agricultural product, which is non-transferable.

2.5.2. Types of contract farming

According to Mighell & Jones (1963), contract farming can be classified into three main categories: marketing contract, production contract and a resource-providing contract.

A marketing contract is a pre-harvest agreement between a farmer and a contractor regarding terms such as price, quantity, quality, time, and product attributes. However, the farmer bears production risks. In a production contract, the contractor specifies how to grow the commodity. Terms such as harvest time, pesticides use and planting area suggested by the contractor should be agreed by the farmer. In this case, the contractor bears the market risks. In a resource-providing contract, the contractor provides agricultural inputs and technical assistance on credit. According to Minot (2011), many contracts combine some characteristics of these three types of contracts.

Contract farming can also be subdivided by the type of governance into the centralized model, nucleus-estate model, multipartite model, intermediary model and the informal model (Al-Hassan et al., 2006; Eaton & Shepherd (2001).

The centralized model is a vertical model where the sponsor offers production, processing and packaging services to farmers on their own land. The sponsor can provide from minimal input to maximum where he takes control of all the production aspects. In this model, production inputs are provided and the output can be used at the local, national level or for exports. It is a model with quota allocation and tight quality control.

The nucleus-estate model is a model where the sponsor owns and manages an estate or plantation. Farmers surrounding the estate are then offered a contract to grow crops which are bought for processing and marketing. Most of times, the estate is large providing then a guarantee of throughout for the plant.

The multipartite model involves varieties of organization such as statutory bodies. This model can be derived from the centralized or nucleus-estate model.

The intermediary model is a model where a sponsor links farmers with intermediaries. It is a kind of subcontract. However, the quality and price received by farmers and the production might no more be under the control of the sponsor.

The informal model involves most of time individuals and small companies. This model depends on government agencies for support services (research and extension) because buyers cannot provide those services and have limited funds.

2.5.3. Benefits and disadvantages of contract farming

Contract farming can provide many benefits to farmers such as reduction of production and marketing risk, higher income, higher yields and better access to agricultural inputs, technical support, knowledge, introduction of a new technology, opening up of new markets not available for farmers and technology transfer (Barrett et al., 2012; Bellemare, 2012; Bijman, 2008; Eaton & Shepherd, 2001; Melese, 2012; Singh, 2002; Velde &

Maertens, 2014). Contract farming can also provide disadvantages. These disadvantages include: loss of autonomy, production risk, market failure, and domination by monopoly position of contractor, unequal power relationship, manipulation of quotas and quality specifications, corruption, risk of indebtedness, overreliance on advances, threat to cultural pattern, shift of food crops to cash crops and income reduction (Mwambi, Oduol, Mshenga, & Saidi, 2016; Smalley, 2013). In developing countries, although a lot of studies have shown that contract farming is beneficial for farmers, others revealed some disadvantages for farmers.

Bellemare (2012) studied the impact of participating in contract farming on the welfare of the growers in 22 regions of Madagascar. The contracted crops were rice, maize, cotton, green beans and barley. Using a contingent-valuation experiment he found that a 1-percent increase in the likelihood of participating in contract farming is associated with a 0.6-percent increase in household income of and a 0.5-percent increase in household income per adult equivalent.

Kalimangasi, Nathaniel, Kihombo, & Kalimangasi (2014) studied the technical efficiency of cocoa productivity through contract farming in Kilombero and Kyela Districts of Tanzania for improving livelihoods of smallholder farmers. The authors showed that the mean technical efficiency was 79.7% and 61.6% from Kilombero and Kyela Districts respectively. Using a qualitative analysis, the farmers agreed that being in contract had increased access of training, credit access, timely purchase, timely payment, production quantity increasing and labor training.

Kufoalor (2013) studied the impact of contract farming on pineapple farmers' performance (gross margins and yield) in the Eastern Region of Ghana. Using the propensity Score Matching method, the study found that, smallholder farmers under contractual arrangements earned higher average gross margins and higher average yields compared to independent farmers

Mwambi et al. (2016) studied the impact of contract farming on avocado smallholder farmers' income in Kandara District in Kenya. They employed an instrumental variable model (Probit-2 stage least square).The authors found participants in contract farming had higher incomes. However, the differences in income of the two treatment groups are not significant. The variation in income can then not be attributed to participation in contract farming.

- **Contractual arrangements for bioenergy development**

Due to the lack of established markets for bioenergy crops, contract farming appears to be an incentive for farmers to grow bioenergy crops. Perennial energy crops such as Jatropha are usually sold under production contracts and so decrease the perceived risk and uncertainty (Alexander et al., 2012). Bioenergy crop cultivation always requires the set up and management of integrated and coordinated supply chains (Cembalo, Pascucci, Tagliafierro, & Caracciolo, 2014). The aim is for the bioenergy company to secure the bioenergy crop production. It is so in the bioenergy company's interest to design proper supply chain arrangements such that many farmers agree to deliver their production as scheduled. Contract farming is also used to manage integration, coordination and cooperation (Abebe, Bijman, Kemp, Omta, & Tsegaye, 2013) and address market failures (Barrett, 2008). Biofuel investors using out grower schemes have little direct negative impacts on land access and represent the most positive model for local livelihoods and the environment (Mshandete, 2011; Sulle & Nelson, 2009). However, households producing bioenergy crops under contract do not necessarily sacrifice their ability to feed themselves but rather bear the risk of reducing their own food production (Locke & Henley, 2014).

2.5.4. Stated preference elicitation approaches: Contingent Valuation vs Discrete Choice Experiment

Stated preference approaches are methods used to estimate the value of goods and services not commonly bought and sold in existing markets (Vega & Alpizar, 2011). Due to no functional markets, these methods create hypothetical scenarios in which agents make decisions that mimic the reality of markets (Mitchell & Carson, 1989; Vega & Alpizar, 2011). Methods using stated preferences are opposed to those using revealed preferences which rely on data from real markets.

Contingent valuation method is a stated preference method where individuals are directly asked their maximum willingness to pay (or minimum willingness to accept) for hypothetical or real goods (Mitchell & Carson, 1989). Contingent valuation can use either an open question such as “what is your maximum WTP?”, or a referendum style question such as “would you be willing to pay GH₵ x?” The respondent is expected to answer “yes” or “no. A range of different values or bids is randomly assigned to different respondents. In order to decide on the range of values, several factors are taken into consideration (Gunatilake, Yang, Pattanayak, & Choe, 2007). Bids should be realistic. In order words bids should be close to the value of the good or service. Through literature review, background information and focus group discussions the researcher can determine the range of values. However according to Whittington (1998), the lowest value of WTP should be low enough that most of the respondents will accept it and the highest value high enough that most respondents will reject it.

The use of contingent valuation has been criticized both for its ability to deliver reliable and accurate estimates of the willingness to pay and the design of contingent valuation surveys (Diamond & Hausman, 1994).

Discrete choice experiment is also a stated preference approach that has its origin in conjoint analysis. It was initially developed in marketing and transport studies (Louviere & Hensher, 1982; Louviere & Woodworth, 1983). In a discrete choice experiment, individuals make repeated choices between different bundles of goods. Individuals are then presented with a series of choice sets where the different goods are defined by their attributes. Most of the times, each choice set contain three or more alternatives. An alternative is defined as a combination of different attributes taking on a value called level. From each choice set, individuals choose their preferred alternative. In other words, the individual makes a discrete choice meaning that it is only possible for him/her to choose one alternative in a choice set. The attributes used are similar across all alternatives. However, the levels of each attribute vary from one alternative to another depending on the experimental design. Train (1993) defines a discrete choice as a situation in which the individual makes a choice among a set of alternatives meeting the following criteria: The number of alternatives in a choice set is finite, the alternatives are mutually exclusive and all possible alternatives are included. Generally, a price attribute representing the cost of the good is incorporated in order to derive welfare estimates. The discrete choice experiment provides the following information (Hanley et al.,1998): Attributes that significantly influence choice, attributes' rank, the marginal willingness to pay for an increase or decrease in any significant attribute and the implied willingness to pay for a programme which changes more than one attribute simultaneously.

Discrete choice experiment offers several advantages compared to contingent valuation. First, discrete choice experiment provides additional information compared to contingent valuation since it allows estimating not only the mean willingness to pay, but also the implicit price or marginal WTP for the different attributes considered in the experiment (Hoyos, 2010; Mahieu, Henrik, Beaumais, Crastes, & Wolff, 2014). Secondly, according to N. Hanley, Mourato, & Wright, (2001), discrete choice experiment may reduce ethical protesting in the sense that the choice context is less stark than the direct elicitation of willingness to pay of contingent valuation. Thirdly, discrete choice experiment provides an opportunity to have a good understanding of the trade-offs between different attributes (W. Adamowicz, Boxall, Williams, & Louviere, 1998). However, discrete choice may place a higher cognitive burden on the respondents, especially in cases where the number of alternatives and attributes in the choice set is high or the number of repeated choices to be made is large (Hoyos, 2010; Mahieu et al., 2014; Swait & Adamowicz, 2001). There are no guidelines on the number of attributes to be included in a DCE study. However in practice, most DCEs have contained less than 10 attributes to ensure that respondents are able to consider all attributes listed when making their choice (Abebe et al., 2013; Bergtold, Fewell, & Williams, 2014; Cembalo et al., 2014; Costedoat, Koetse, Corbera, & Ezzine-de-blas, 2016; Greiner, 2015; Interis & Cordero-salas, 2016; Krah et al., 2015; Qin, Carlsson, & Xu, 2009).

2.5.5. Design of the discrete choice experiment

The design of the discrete choice experiment is made of five steps: Identification of attributes, definition of levels, experimental design, construction of questionnaire and data collection and data analysis (Mangham, Hanson, & Mcpake, 2009).

Step one: Identification of attributes

The selection and definition of attributes require a good understanding of the population's perspective and experience (Coast & Horrocks, 2007; Hall, Viney, Haas, & Louviere, 2004). This first step also requires literature review and qualitative research, such as focus groups and discussions with local experts (World Health Organization, 2012). There is no restriction concerning the numbers of attributes to be considered in a discrete choice experiment. However, majority of studies have used less than 10 attributes in order to make sure that respondents consider all the attributes before making their choice rather than considering a single or subset of attributes (DeShazo & Fermo, 2002). According to Mangham et al. (2009), if there are too many attributes, then the respondents might face cognitive difficulty of completing the experiment. They also encourage researchers to avoid selecting attributes that have a correlation because it might prevent the accurate estimation of the main effect of a single attribute on the choice variable. Other contractual arrangement such as quality was not included in the analysis firstly because the study assumed that the seed should meet a minimum quality standard.

Step two: Definition of levels

Hall et al. (2004) suggested that the definition of levels should be meaningful and realistic in order to get precise parameter estimates. Ryan (1999) defined factors to consider when choosing the levels for each attribute: plausible levels for the respondents, actionable levels for the respondents and levels inciting respondents to make trade-offs between combinations of the attributes. Levels can be defined as a continuous or categorical variables (Mangham et al., 2009). Continuous variables can take any numeric value. Categorical variables are variables associated with levels belonging to categories. Consequently, the levels of categorical variables need to be defined and stated clearly for the respondents not to have wrong interpretation.

Step three: Experimental design

Bennett & Blamey (2001) defined experimental design as the way in which the alternatives are generated and combined into choice sets. A full factorial design consists of all possible alternatives or combinations of the levels of the attributes (Sydorovych & Wossink, 2008). If the number of levels differs across attributes, the full factorial design consists of: $a^n \times b^m$. Where a and b represent the different levels and n and m the different attributes. However, most of the times, full factorial design generates a lot of choice sets difficult for a respondent to answer them all. Fractional factorial designs are then employed to reduce and select possible alternatives in which the properties of the full factorial design are maintained in the best way (Mangham et al., 2009; World Health Organization, 2012). An optimal fractional factorial design should be both orthogonal and balanced (Kuhfeld, 2005). A design is orthogonal if attributes are statistically independent of one another. However, a design is qualified as balanced if attributes levels appear in an equal number of times minimizing then the parameters variance (Kuhfeld, 2005). Fractional factorial designs that are both orthogonal and balanced are called orthogonal arrays. Orthogonal arrays can be obtained from design catalogues (Hahn &

Shapiro, 1966), statistical programs such as SPSS and websites (Sloane, 2009). However, orthogonal arrays only exist for specific combinations of attributes and levels (Kuhfeld, 2005; Mangham et al., 2009). For combinations that differ from those required for orthogonal arrays, a D-efficient design is encouraged (Kuhfeld, 2005). Efficient designs should also meet the property of minimum overlap (World Health Organization, 2012). The property of minimum overlap means that attributes levels are not the same within a choice set. Mangham et al. (2009) encouraged researchers to minimize the probability that a level repeats itself within a choice set.

Experimental designs are associated with challenges (World Health Organization, 2012). The challenges are: Statistical and respondent efficiency, number of choices and cognitive fatigue and choice of including an opt-out option (status quo) or not.

The purpose of experimental design methods is to maximize the efficiency of the design, while sometimes neglecting the market realism. However, Louviere, Hensher, & Swait (2000) stated that experimental design should consider market realism because the more an experiment resembles the actual market, the higher its content validity. Researchers should then balance statistical efficiency against respondent efficiency (World Health Organization, 2012).

The number of choice sets to be presented to each respondent depends on the experimental design method used. Sometimes, even after the use of experimental design methods such as fractional factorial design, a large number of choices to be presented to the respondents might remain (World Health Organization, 2012). Presenting a lot of choice sets for the respondent to make can be tiring and boring. Most discrete choice experiment studies have consider up to 18 choice sets (Hanson, McPake, Nakamba, & Archard, 2005). The pretest is the best way to assess the feasibility of the number of choice sets to be presented to respondents and block design into small sets if necessary (World Health Organization, 2012).

According to World Health Organization (2012), the omission of an opt-out option (status quo alternative) forces the respondent to choose between less important alternatives likely to generate biased parameter estimates. However, adding an opt-out option may lead respondents to choose it not because it provides the highest utility compared to the other alternatives but rather to avoid making a difficult decision. World Health Organization (2012) encouraged researchers to incorporate an opt-out alternative since majority of discrete choice experiment studies calculate welfare estimates such as willingness to pay and willingness to accept.

Step four: Construction of questionnaire and data collection

According to Mangham et al. (2009), the choices generated from the experimental design stage form the basis of the discrete choice experiment questionnaire. The questionnaire should start with an introduction to the discrete choice experiment with choice set examples. Kjaer, Bech, Gyrd-Hansen, & Hart-Hansen (2006) suggested producing diverse versions of the questionnaire in which the choice sets are presented in different orders in other to minimize bias. Mangham et al. (2009) also encouraged the use of pictures, diagrams and symbols in low or middle income countries where literacy cannot be assumed. Additionally, the authors also suggested translating the questionnaire in local languages might be required in low or middle income countries.

Discrete choice experiment questionnaire can be self-administered, undertaken in examination setting (Chomitz, Setiadi, Azwar, Ismail, & Widiyarti, 1998), administered through trained fieldworkers interviewing respondents individually (Mangham et al., 2009), administered through telephone interview or mailed questionnaires (Bennett & Blamey, 2001). Hall et al. (2004) required undertaking a pretest of the questionnaire in order to ensure the selection and definition of attributes and levels.

World Health Organization (2012) suggested incorporating a section on the socioeconomic characteristics of respondents to the discrete choice experiment questionnaire.

Step five: Data analysis

After data collection, data can be entered using data entry programs such as CSPRo, Excel, EpiInfo and SPSS (World Health Organization, 2012). Each choice set contains information on the attribute levels of each alternative, and the chosen alternative by the respondent. Each respondent will be allocated several rows of data in the final discrete choice experiment dataset, depending on whether the choices presented were either binary, forced, or multiple and including an opt-out option or not.

Discrete choice experiment has its theoretical foundation in the random utility theory (Hall et al., 2004; McFadden, 1973; Train, 2009). The random utility theory assumes that the utility associated with any alternative can be divided into a sum of observable and non-observable factors by researcher, and hence is assumed random. The utility of an individual i derives from choosing an alternative j can be expressed as a combination of both deterministic and stochastic element such as:

$$U_{ij} = X_{ij}\beta + \varepsilon_{ij} \tag{2.1}$$

Where β is the vector of non-observed variables to be estimated representing the tastes of the individual. X_{ij} is the vector of observed explanatory relating to individual i and to alternative j; and ε_{ij} is the random error term. The individual i will choose the alternative j generating the highest utility. Depending on the assumptions made by the researcher concerning the error term and the experimental design of the discrete choice experiment, several econometric models can be employed to analyze discrete choice experiment data.

The use of Multinomial Logit model (McFadden, 1973) is based on three assumptions. Firstly, the random terms of the utilities of the different alternatives are independent and identically distributed (IID) with a Type I extreme-value distribution also known as Gumbel distribution. The assumption of independence refers to the fact that there are no common unobserved factors influencing the utilities of the diverse alternatives. Secondly, the Multinomial Logit assumes that preferences are homogenous. Lastly, the model assumes that the error variance-covariance of the alternatives is identical across individuals. The Multinomial Logit model is similar to the Conditional Logit model. However, the main difference between them lies in the fact that in the Multinomial Logit variables are conditioned to not change across alternatives making variables to be specific to the individual but not to the alternatives (Wooldridge, 2010). The Conditional Logit model is restricted under the assumption of Independence of Irrelevant Alternatives (IIA) (Louviere et al., 2000; Wooldridge, 2010). The IIA assumption refers to the fact that the introduction or removal of an alternative has no effect on the proportion of probability assigned to each of the other alternatives.

The Nested Logit model (Williams, 1977) is an extension of Multinomial Logit model in considering the existence of an additional error component representing correlation between alternatives. This model groups similar alternatives into nests. A latent class model sort individuals into classes based on their preferred attributes, so that individuals with similar preferences are grouped in the same class.

The mixed logit model also known as Random Parameter Logit (RPL) model has been developed to allow for unobserved heterogeneity of preferences (Hensher & Greene, 2003; Louviere et al., 2000). Preference heterogeneity is incorporated by allowing the coefficients of the attributes as random rather than fixed in order to account for unobserved variation in respondents' preferences. Additionally, mixed logit models can easily accommodate any random utility model (McFadden & Train, 2000). Mixed logit model confers many advantages that are limitations of the standard Multinomial logit model. Firstly, it relaxes the restrictive IIA assumption. Secondly, attributes can vary according to defined statistical distributions. Thirdly, preferences heterogeneity can be modelled by incorporating interaction terms of socioeconomic variables. However, the interaction terms are freely chosen by the researcher. From Equation 2.1, instead of assuming β as a fixed coefficient, the Random Parameter Logit assumes that β varies among the respondents. β_i is then random and can be decomposed into the coefficient' mean β and deviations v_i. It results that:

$$\beta_i = \beta + v_i \tag{2.2}$$

The random term v_i captures non-observable individual effects. According to Train (2002), the utility function becomes then:

$$U_{ij} = X_{ij}\beta + \varepsilon_{ij} = (\beta + v_i) X_{ij} + \varepsilon_{ij} \tag{2.3}$$

The Random Parameter Logit model assumes that each random coefficient follows a specific distribution. The most common are: normal, log normal, triangular and uniform distributions (Hensher & Greene, 2003).

2.5.6. Welfare estimates and its confidence intervals

Welfare estimates, Willingness To Pay and Willingness To Accept for instance are calculated using the ratio of an attribute parameter to the cost parameter (Louviere et al., 2000; McFadden, 1973). Two methods are generally used to calculate the confidence intervals of the Willingness To Pay: the Delta method (Greene, 2004) and the Krinsky and Robb parametric bootstrapping (Krinsky & Robb, 1990). Krinsky & Robb's (1990) procedure consists of taking a large number of draws from a multivariate normal distribution with means and covariance respectively given by the estimated coefficients and the estimated covariance matrix of the coefficients. This method uses Monte Carlo simulation. The estimate of the variance of a non-linear function of random variables using the delta method is obtained by taking the first-order Taylor expansion around the mean value of the variables and calculating the variance for this expression (Greene, 2004). The Delta method does not rely on simulation approaches. It gives an accurate exact expression for the standard error of welfare estimates, while simulation approaches give approximation of the confidence intervals.

2.5.7. Empirical literature review on stated preferences elicitation

Costedoat, Koetse, Corbera, & Ezzine-de-blas (2016) used a discrete choice experiment to estimate community forest owners' preferences for Payments for Ecosystem Services (PES) contract in Chiapas, Mexico. They used both Multinomial Logit and Latent Class models to analyze preferences. The attributes considered were: the decision regarding spatial location of forest parcels to be included in the programme, technical service provider, the payment level and the use of payment (the distribution of benefits for participating in PES. The landowners have the choice between receiving individual cash payment, or in case of collective contracts the payment is distributed as follow: 50%/50% between individual cash and a social project aimed at improving the community's wellbeing (e.g., school, clinic, or maintaining infrastructure such as public lights or roads) or 50%/50% between individual cash and in the form of bank savings used to buy tractors for participants in PES that have complied with contract terms after a five-year period (50%)). They found that respondents prefer a PES contract to a situation without any contract. The respondents prefer an individual decision rather than collective decision regarding what forest parcel to include in the programme, an external service provider, and 100 percent each payment.

Qin, Carlsson, & Xu (2009) studied farmers' preferences for various property-rights attributes of a forestland contract in China. Using a Random Parameter Logit model, the authors found that farmers have a positive preference for the attributes "no risk of termination" and "a first right to renew an expired contract". Additionally, an extended waiting time for rights to harvest the forest reduces the farmer's perceived value of a contract. In Jinping Region, older farmers are less likely to enter into contract. In Majiang

Region, farmers who preferred to use auction to transfer the forest land were more likely to take a contract.

Interis & Cordero-salas (2016) studied farmers' preferences for production contract in Northern Ghana. The products were: Tomato, tilapia, rice, cassava, pineapple, palm oil, soyabean and maize. Using a conditional logit model, they found that farmers are most likely to enter into contract having the following characteristics: written, support from the buyer in the form of seed, fertilizers and pesticides and familiarity with the buyer. They also found that farmers are less likely to enter into contracts allowing side-selling and specify a quality option.

Bergtold et al. (2014) used a discrete choice experiment to examine farmers' willingness to grow three bioenergy crops (corn stover, sweet sorghum, and switchgrass) under alternative contractual arrangements in Kansas. Using a conditional logit, they found that the level of net returns above the next best alternative land-use, contract length, having a biorefinery harvest option, availability of insurance, and having monetary incentives share are important attributes that farmers value.

Cembalo et al. (2014) analyzed farmers' preferences for biomass contract attributes using discrete choice experiment in Southern Italy. Using a Random Parameter Logit model, they found that participation is mainly influenced by minimum price guaranteed, contract length, and re-negotiation before the end of a contract.

Using a Random Parameter Logit model, Abebe et al. (2013) found that farmers' willingness to participate in contract farming increases if a contract design has the following attributes: a written form; inputs, technical assistance, and seed supplied by the buyer firm; and variable output quality and price options.

Greiner (2015) employed a discrete choice experiment to understand Australian pastoralists' preferences for biodiversity conservation contracts attributes. Using both a Random Parameter Logit and a Latent Class models, they found that conservation requirement, conservation payment, contract length, flexibility and monitoring arrangements influence choices. In addition, they concluded that there is heterogeneity of preferences for all contract attributes.

Krah et al. (2015) employed a discrete choice experiment to analyze farmer preferences for contracts to cultivate Giant Miscanthus in the US. Using a Random Parameter Logit model, the authors showed that price, biorefinery harvest, and establishment cost-share influence positively the probability for a farmer to accept a contract. They also found that there is a significant preference heterogeneity in producer preferences and concluded that taking into account risk perception and preference in their model specification improves the overall model performance. Indeed, factors such as subjective risk perceptions and risk preferences do influence farmers' decisions subject to risky choices (Lusk & Coble, 2005; Pennings & Garcia, 2001; Petrolia, Landry, & Coble, 2013; Petrolia, 2016). The present study goes beyond Krah et al. (2015) by incorporating socio economic characteristics of farmers in order to identify potential sources of heterogeneity.

CHAPTER THREE

METHODOLOGY

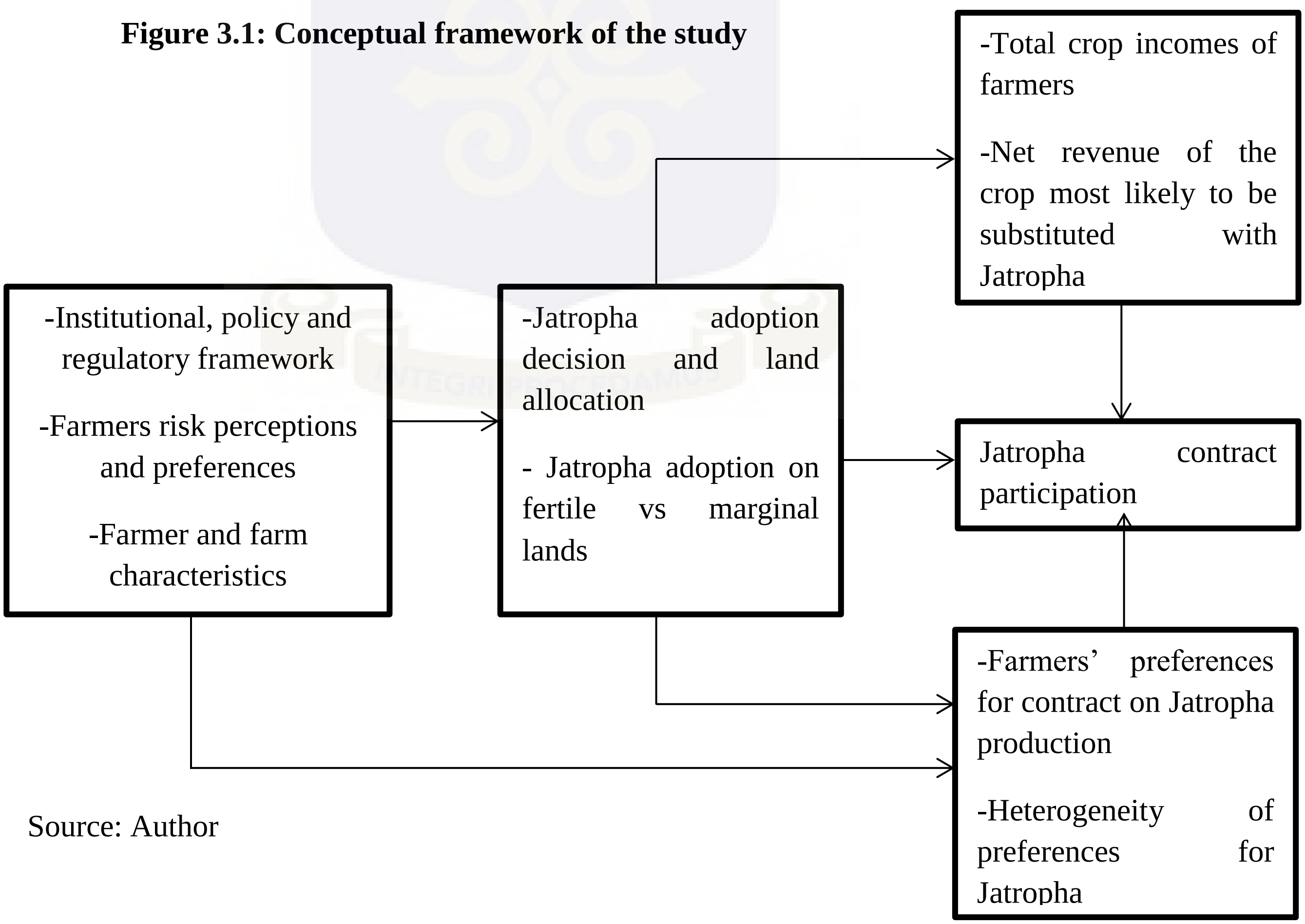
3.1. Introduction

This chapter describes the methodology of the study looking at the conceptual framework, the methods of analyses of the different objectives, data required, sampling method, data collection and the study area. The limitations of the study are presented in the final section.

3.2. Conceptual Framework

The relationships between the cause and outcomes variables are presented in the flow chart (Figure 3.1). The adoption of a perennial crop such as Jatropha is influenced by farm and farmer characteristics. For instance, Feder, Just, & Zilberman (1985) showed that, farm size can influence adoption depending on the fixed costs inherent in the new technology adoption, risk preferences, credit access and labour among others. When the size of the farm is small, the fixed costs per unit of outpuare large reducing the probability of adoption. Small farms characterized with large fixed costs are less prone to technology adoption. Characteristics such as age, education, gender, livestock ownership, farming experience and access to extension services also influence the adoption of Jatropha by farmers (Bocquého et al., 2015; Cheteni et al., 2014; Gedikoglu, 2015; Jensen et al., 2007). Jatropha is a perennial crop that can take at least three years to reach full harvest potential. The risk and time preferences of farmers may influence their decision to adopt. Since the returns of Jatropha on fertile and marginal land are different as for any other crop, farm and farmer characteristics also affect their decisions to adopt on these lands. The adoption of Jatropha may increase the level of income of farmers in case the adoption is successful and well monitored and the contracts terms of Jatropha production well aligned with farmers' preferences. The net revenue of the crop most likely crop to be substituted with Jatropha can influence farmers' participation in Jatropha contract. This in the sense that, in case the expected revenue from Jatropha is greater than the revenue of the most likely crop to be substituted with Jatropha, a farmer would be willing to participate in Jatropha contract. Risk perceptions and preferences also affect contract participation and preferences of a risky crop like Jatropha (Lusk & Coble, 2005; Pennings & Garcia, 2001; Petrolia et al., 2013; Petrolia, 2016). Farm and farmers characteristics, market conditions and Jatropha adoption status can influence farmers' preferences to enter into a Jatropha contract and cause heterogeneity in contract preferences.

Figure 3.1: Conceptual framework of the study



Source: Author

3.3. Identifying Factors Influencing Jatropha Adoption

3.3.1. Theoretical framework: Random Utility Theory

Following Hoque et al. (2015), household's decision to adopt bioenergy crop can be analyzed within a random utility framework. Let U_{hA} denotes the utility obtained by household h from adopting Jatropha and U_{hN} the utility of non-adoption. Let Z_h be a vector of farm and household characteristics affecting bioenergy crop adoption decisions and ε_h be the error term. According to the state of adoption, household h utility is approximated as:

$$\begin{cases} U_{hA} = f\left(Z_h\right) + \varepsilon_{hA} \\ U_{hN} = f\left(Z_h\right) + \varepsilon_{hN} \end{cases} \tag{3.1}$$

A household will choose to adopt Jatropha only if the utility derived from adopting is greater than the utility from not adopting: $U_{hA} \succ U_{hN}$. Since these utilities are not observable, they can be expressed in the following latent structure model for adoption of bioenergy crop:

$$V_h^* = \beta Z_h + \varepsilon_h \tag{3.2}$$

$V_h = \begin{cases} 1, & V_h^* \succ 0 \\ 0, & V_h^* \prec 0 \end{cases}$ Where V_h is a binary indicator taking the value of 1 in the case where the household adopts bioenergy crop and 0 otherwise.

3.3.2. Empirical models: the double hurdle model and bivariate probit model

a. Factors explaining farmers' adoption and land allocation to Jatropha in Northern Ghana: a double hurdle model

The study is interested in two decisions made by farmers. The first decision is the decision to adopt Jatropha or not. The second decision is the decision on the total amount of land to be allocated to Jatropha. After data collection, the decisions to adopt and to what extent may lead to generation of several zeros for non-adopters. In order to deal with the zeros, the traditional approach has been to use the standard Tobit model (Tobin, 1958) when the amount of land allocated is available (Jensen et al., 2007; Roos et al., 2000). However, the Tobit assumes that the equation determining the probability of adoption is the same as the equation explaining the intensity of adoption. Cragg's double hurdle model (Cragg, 1971) overcomes this restrictive assumption. In the double hurdle model first, the farmer decides whether or not to adopt the new technology (Jatropha for instance), and second to what extent. In this case, the second decision is the total amount of land allocated to Jatropha. The first equation (Equation 3.3) of the model called the participation equation corresponds to a binary variable. This equation is estimated by a Probit model (Cragg, 1971). The second (Equation 3.4) called the intensity equation corresponds to a positive variable conditional on having adopted in the first decision of adopt. In the double hurdle model, the participation and intensity decisions are generated by distinct or independent underlying processes (Cragg, 1971). Contrary to the Tobit model where it is assumed that these two decisions are affected by the same set of factors (Greene, 2003), the double-hurdle model allows for the possibility that these two decisions are affected by a different set of variables.

Participation equation (Probit regression model)

$$y_i^* = \beta X_i + v_i \tag{3.3}$$

The intensity equation (Truncated regression model) is conditional for non-zero responses in the participation decision and can be expressed as:

$$z_i^* = \gamma W_i + \varepsilon_i \qquad z_i = \begin{cases} z_i^* & if \quad y_i^* \succ 0 \\ 0 & otherwise \end{cases} \tag{3.4}$$

Where X_i the vector of variables explaining participation in Jatropha production; W_i is the vector of variables explaining Jatropha land allocation decision in terms of acreage based on land hoilding. β and γ are vectors of parameters; v_i and ε_i are the error terms distributed as follows: $v_i \sim N(0,1)$ and $\varepsilon_i \sim N(0,\sigma_\varepsilon^2)$.

Following Cragg (1971) the log likelihood function for the double hurdle model is:

$$\ln L(z_i;\gamma,\beta) = \sum_{y_i=0} \ln\left[1-\Phi(\beta X_i)\left(\frac{\gamma W_i}{\sigma_\varepsilon}\right)\right] + \sum_{z_i \succ 0} \ln\left[\Phi(\beta X_i)\frac{1}{\sigma_\varepsilon}\phi\left(\frac{z_i-\gamma W_i}{\sigma_\varepsilon}\right)\right] \tag{3.5}$$

Where Φ and ϕ are the standard normal cumulative distribution and density functions, respectively. The double hurdle log-likelihood is the sum of a Probit regression model and a truncated regression model. The first portion is the log-likelihood for a Probit, while the second portion is the log-likelihood for a truncated regression (Wooldridge, 2010). In cases where $\xi = \dfrac{\gamma}{\sigma_\varepsilon}$ and $X_i = W_i$, then Equation 3.5 is a Tobit model.

In order to compare both models (double hurdle and Tobit models) and find out which one fits better the data, a Likelihood Ratio (LR) test is used. The LR statistic Γ is computed using (Greene, 2000):

$$\Gamma = -2\left[\ln L_{Tobit} - \left(\ln L_{Probit} + \ln L_{Truncated}\right)\right] \sim \chi_k^2 \tag{3.6}$$

Where L_{Tobit} : likelihood of the Tobit model; L_{Probit} : Likelihood of the Probit model;

$L_{Truncated}$: Likelihood of the truncated regression model.

χ_k^2 : chi-squared distribution with k degrees of freedom, k : number of explanatory variables in the equations. The hypothesis is expressed as:

$H_0 : \xi = \frac{\gamma}{\sigma_\varepsilon}$ and $H_1 : \xi \neq \frac{\gamma}{\sigma_\varepsilon}$ H_0 is rejected if $\Gamma \succ \chi_k^2$

When running this test, it is found that the test statistic $\Gamma = 60.2$ is greater than the critical value of the χ^2 distribution. The statistic rejects the Tobit model. Thus, it is better to separate the participation decision from the intensity decision. Consequently, the results will be based on the double hurdle model (Appendix A).

b. Factors explaining farmers' decisions to adopt Jatropha either on fertile or marginal lands in Northern Ghana: a Bivariate Probit model

The bivariate Probit model is used to empirically analyzed Jatropha adoption on either fertile or marginal land. Land resources are heterogeneous; farmers can grow Jatropha either on fertile or marginal land. The use of the Bivariate Probit model is based on the assumption that a farmer decides jointly to grow Jatropha either on marginal or fertile land depending on the expected revenue from the land type (Bocquého et al., 2015). Additionally, it is highly probable that farmers do not have the same performance expectations for crops grown on fertile and marginal land. The study follows Bocquého et al. (2015).

Let z_i be the participation variable on fertile land and y_i the participation variable on marginal land. These are binary variables taking on the value 1 in the case the farmer i allocate a positive amount of land for Jatropha on the given land type and 0 otherwise.

Participation equation for fertile land:

$$z_i^* = \gamma X_i + \varepsilon_i \qquad z_i = \begin{cases} z_i^* & if \ \ z_i^* \succ 0 \\ 0 & otherwise \end{cases} \tag{3.7}$$

Participation equation for marginal land:

$$y_i^* = \beta X_i + v_i \qquad y_i = \begin{cases} y_i^* & if \ \ y_i^* \succ 0 \\ 0 & otherwise \end{cases} \tag{3.8}$$

Where X_i is the vector of explanatory variables. β and γ are vectors of parameters; v_i and ε_i are the error terms. The correlated error terms are assumed to follow a bivariate normal distribution: $\begin{pmatrix} v_i \\ \varepsilon_i \end{pmatrix} \sim N(0, \Sigma)$. $\Sigma = \begin{pmatrix} 1 & \sigma\rho \\ \sigma\rho & \sigma^2 \end{pmatrix}$ and ρ is the coefficient of correlation.

y_i^* and z_i^* are two dummy variables equal to 1 if the farmer i allocated fertile and marginal land respectively to Jatropha.

3.3.3. Variable description for factors affecting adoption and land allocation to Jatropha and their justification

The variables used in factors affecting Jatropha adoption and its extent are shown in Table 3.1.

Step one:

The first step of the double hurdle model involves the participation decision of adopting Jatropha.

The dependent variable is Jatropha adoption status taking the value 1 if the farmer is growing Jatropha or 0 otherwise

The independent variables are:

Gender of the farmer: According to Mapemba, Grevulo, & Mulagha (2013), male farmers are more likely to adopt Jatropha as a bioenergy crop. In Ghana and especially in the Northern Region, female farmers are less likely to adopt new technologies. Women have very little access and control over resources due to patriarchy. They face challenges such as unequal access to land, finance and credit, etc. In addition, men manage cash crops activities in the farm. The sign of this variable is expected to be negative.

Age of the farmer: Young farmers are assumed to have more years ahead to receive the returns from their investment especially when a perennial crop such as Jatropha is concerned. Older farmers are more reluctant to change (Bocquého, 2011). The expected sign will be negative.

Education of the farmer: Education is assumed to provide knowledge to the farmer, allowing him/her to access and use information. Being educated could lead farmers to understand the importance of a new crop variety (Jatropha) on the farm. The expected sign will be positive.

Number of adults in the household for farm work: The number of adult members of the household could provide labour needed for production since Jatropha is known as a labour intensive crop (Achten et al., 2008). Adult members in the household may provide adequate labour for Jatropha cultivation. The expected sign will be positive.

Farming experience: Experience is informal education. The longer the time a farmer has spent in the farming occupation, the more experience he or she has in farming. Farming experience is expected to have a positive influence on Jatropha adoption.

Farm size: Small farms bear large fixed costs making them less prone to adopt a new technology. Investment in Jatropha requires a substantial amount of initial set-up or establishment cost. This type of technology is called “lumpy technology”. Feder et al. (1985) showed that only large farms adopt “lumpy technology”. The expected sign will be positive.

Extension services: Extension services enable farmers to get information and knowledge about new techniques or new crop varieties. These information and knowledge serve as a guidance tool for farmers when coming to decision making of adopting a new technology. It is expected that access to extension services positively influences adoption of Jatropha.

Off-farm activities: Engagement in off-farm activities provides farmers with additional income enabling them to improve their wellbeing. The more a farmer is engaged in off-farm activities the higher the ability to invest in Jatropha cultivation. In addition, since Jatropha is a new crop with a 3-4 years gestation period (Carels, Sujatha, & Bahadur, 2012), engagement in off-farm activities provide funds to cover the lengthy gestation period of Jatropha. The expected sign will be positive.

Livestock ownership: Having livestock in the farm could be understood as having less land available for Jatropha production. The expected sign will be negative.

Membership of Farmer Based Organization: A Farmer Based Organization (FBO) helps farmers to find markets for their products. It also helps farmers to access credit under the FBO umbrella. Membership to FBO is expected to positively influence Jatropha adoption.

District: This variable distinguishes farmers from Mion and West Mamprusi Districts. Farmers from the West Mamprusi District face challenges in selling Jatropha grains compared to those from Mion District (Field Survey). The sign is expected to be negative

Access to credit: Access was measured as applied for and received borrowed funds from informal or formal sector. Since Jatropha requires a long gestation period; access to credit can help farmers meet the costs of establishment and maintenance of Jatropha. The expected sign on the coefficient is positive.

Distance to market: Jatropha seeds are not harvested frequently and can be stored Jatropha is not sold to any specific agricultural market. It is sold to Non-governmental Organizations (NGO) such as New Energy. Distance to the nearest agricultural market is expected to have a negative influence on the probability of Jatropha adoption.

Size of land owned: Since Jatropha is a perennial crop, it is not that easy to be removed from the ground. To invest in such a crop with long term returns necessitates that the farmer owns the land. It is expected that size of land owned positively influences Jatropha adoption.

Hired labour: Jatropha is labour intensive; farmers who have the capacity to hire more labour (number of man-days) during the cropping season could have the incentive to adopt Jatropha. The expected sign on the coefficient is positive.

Irrigation: Jatropha is said to be drought-resistant, able to grow under non-irrigated conditions with only water from rainfall. However, Jatropha needs proper and constant water supply to achieve its yield potential (Carels et al., 2012). The practice of irrigation is expected to have a positive influence on Jatropha adoption.

Risk attitude: This variable is a continuous variable ranging from 0 (severely risk averse) to 10 (fully risk lover). Following Dohmen, Falk, Huffman, & Sunde (2012), the self-assessment risk attitude are measured using the exact wording: *How do you see yourself: Are you a person who takes risk or do you try to avoid risks? Please self-grade your choice (ranging between 0-10), where the grades run from 0: "not at all prepared to take risk" to 10: "very much prepared to take risk".* Jatropha is a perennial crop that can take at least three years to reach full harvest potential. It is expected that the more risk lover the farmer is the more he/she would adopt Jatropha. The sign is expected to be positive.

Discount factor

Discount factor is included in this study because the decision to invest in Jatropha given that Jatropha only commences to remunerate in three years' time will be impacted by how the investment is discounted in the future. A simple measure of discounting was collected using a single question as follows:*" Which of the following choices would you prefer: (1) Receive 10 GH¢ today. OR (2) Receive 15 GH¢ in one month?"* With this single question the cut off, which is similar to the minimum rate an investor will receive if he/she invests his money is calculated as $\frac{1}{1+r}$, where r is the discount rate, such as $r=\left(\frac{high\ bid}{low\ bid}\right)-1$. If the discount rate is lower than the cut off it means farmers who make the choice of option 2 have a high preference for the future compared to those who make the choice of option 1. If the discount rate is greater than the cut off it means farmers who make the choice of option 1 have a low preference for the future. The discount rate is found to be 0.5 and the cut off 0.67. The discount rate is lower than the cut off. A binary variable is then generated taking the value of 1 for the choice of option 2, high preference for the future and 0 otherwise.

The study expects that farmers who made the choice of option 2 were more likely to adopt Jatropha as Jatropha is a perennial crop which matures after 3 years of investment.

Step two:

The second step of the double hurdle model measures the intensity decision of adopting Jatropha

The dependent variable is the amount of land allocated to Jatropha in hectares (continuous variable)

The independent variables are:

Gender of the farmer: Since women have little control over resources and usually are not much involve in cash crop activities, it is expected that gender has a negative influence on Jatropha land allocation.

Age of the farmer: According to Bocquého (2011) Older farmers are more reluctant to change and less willing to take risks. It is expected that the older the farmer the less the quantity of land he/she allocates to Jatropha. The expected sign on the coefficient is negative.

Education of the farmer: It is expected that the more educated the farmer is, the more land acreage he/she would allocate to Jatropha. Education equips farmers the ability to perceive, interpret and respond to new information. The expected sign on the coefficient is positive

Number of adults of the household: The higher the number of adults in the household for farm work, the more likely the farmer would increase his/her land area under Jatropha. The more the adults in the household the more labour available for Jatropha cultivation. The expected sign on the coefficient is positive.

Farming experience: Depending on the farmer' experience in farming, he/she may decide to increase his/her area under Jatropha. The expected sign on the coefficient is positive.

Farm size: Farm size is expected to have a positive influence on Jatropha acreage allocation. Larger farms can easily allocate more land to Jatropha cultivation without worrying about food security of the family. The expected sign is therefore positive.

Extension services: Through access to extension services, farmers acquire knowledge and advices about land management, new techniques, etc. It is expected that access to extension services positively influences Jatropha land allocation.

Off-farm activities: Engagement in off-farm activities provides farmers with additional income enabling them to improve their wellbeing. This additional income can enable farmers to hire labour. The more a farmer is engaged in off-farm activities the less time he/she would have to run his/her farm. It is expected that engagement in off-farm activities has a negative influence on Jatropha land allocation.

Livestock ownership: Livestock occupies the land. Owning livestock could reduce Jatropha land allocation. The expected sign will be negative.

Membership of Farmer Based Organization: Membership of Farmer Based Organization (FBO) exposes farmers to new market opportunities and their possible benefits. Membership to FBO is expected to positively influence Jatropha land allocation.

District: This variable distinguishes farmers from Mion District to those from West Mamprusi District. Most farmers in West Mamprusi District are not able to sell their Jatropha seeds compared to those from Mion District. Being in West Mamprusi District is expected to have a negative influence on Jatropha land allocation compared to those in Mion District.

Access to credit: Through access to credit, farmers can obtain additional income to get inputs and increase Jatropha land allocation. Access to extension services is expected to have a positive influence on Jatropha land allocation.

Distance to market: Since Jatropha is currently sold to NGOs such as New Energy. Distance to the nearest agricultural market is expected to have a negative effect on Jatropha land allocation.

Size of land owned: The more the size of the land owned the more land a farmer could allocate to Jatropha. It is expected that size of land owned positively influences Jatropha land allocation.

Hired labour: The more hired labour, the more land could be cultivated under Jatropha. The number of man-days of hired labour is expected to have a positive influence on Jatropha land allocation.

Irrigation: Jatropha has the ability to grow on marginal lands with minimum inputs such as water. However adequate water supply can help achieve normal yields. The practice of irrigation is expected to have a positive influence on Jatropha land allocation.

Risk attitude: The more risk lover the farmer is the more he/she will allocate land to Jatropha cultivation. The sign on the coefficient is expected to be positive.

Table 3.1: Variables definition for adoption and land allocation to Jatropha

Variable	Type	Definition and measurement
		Dependent variables
Adopter	Dummy	1 = Grows Jatropha, 0 = Does not grow Jatropha
Jatropha Land allocation	Continuous	Amount of land allocated to Jatropha (hectares)
		Independent variables
Gender	Dummy	Gender of the respondent 0 = male, 1 = female
Age	Continuous	Age of the respondent (in years)
Education	Continuous	Level of education of the respondent in years
Number of adults	Continuous	Number of adult members of the household (Count units)
Farming Experience	Continuous	Farming experience of the respondent (years)
Farm Size	Continuous	Farm size (hectares)
Extension Services	Continuous	Number of times the respondent had access to extension services
Off-farm Activities	Dummy	Engagement in off-farm activities 0 = No, 1 = yes
Livestock	Dummy	Livestock ownership 0 = No, 1 = yes
FBO	Dummy	Farmer based organization membership 0 = No, 1 = yes
District	Dummy	0 = Mion, 1 = West Mamprusi
Credit Access	Dummy	Access to credit 0 = No, 1 = yes
Distance to Market	Continuous	Distance from home to the nearest agricultural market (in km)
Size of land owned	Continuous	Size of land owned (in hectares)
Hired Labour	Continuous	Number of man-days hired during 2014 cropping season
Irrigation	Dummy	Practice of irrigation 0 = No, 1 = yes
Risk Attitude	Continuous	Degree of Risk attitude
Discount Factor	Dummy	1=preference for present , 0 otherwise

Source: Author

3.3.4. Variable description for factors affecting Jatropha adoption on marginal and fertile land and their justification

The variables affecting Jatropha adoption on marginal and fertile lands are shown in Table 3.2.

The dependent variables are:

Fertile land: Jatropha adoption on fertile land taking the value 1 if farmer grows Jatropha on fertile land and 0 otherwise.

Marginal land: Jatropha adoption on marginal land taking the value 1 if farmer grows Jatropha on marginal land and 0 otherwise.

The independent variables tested are the one used in Jatropha adoption. same independent variables used in Jatropha adoption are also used in Jatropha cultivation in either marginal or fertile land. The intuition for the adoption on fertile land follows the intuition used for Jatropha adoption. However, some variables such as livestock, risk attitude and credit might have a different relationship with Jatropha adoption on marginal land.

Risk attitude: Farmers could consider that growing Jatropha on fertile land is more risky than on marginal land, because it locks up a very profitable plot for a long time. It is expected that the more the farmer is risk loving the more he/she would grow Jatropha on fertile land and tle less he/she would grow on marginal land.

Livestock: Marginal land may be used as pasture for animal feeding. It is expected that having livestock would reduce the probability of adopting Jatropha on marginal and increase the probability of adopting on fertile land.

Access to credit: It is said that Jatropha can perform well on marginal land with minimum inputs. However, farmers might use the credit to hire labour to work in Jatropha field. This could lead to a positive sign of this coefficient on both fertile and marginal lands.

Table 3.2: Variables definition for adoption adoption on fertile and marginal lands

Variable	Type	Definition and measurement
		Dependent variables
Fertile land	Dummy	1 = grows Jatropha on fertile land, 0 = No
Marginal land	Dummy	1 = grows Jatropha on marginal land, 0 = No
		Independent variables
Gender	Dummy	Gender of the respondent 0 = male, 1 = female
Age	Continuous	Age of the respondent (in years)
Education	Continuous	Level of education of the respondent in years
Number of adults	Continuous	Number of adult members of the household (Count units)
Farming Experience	Continuous	Farming experience of the respondent (years)
Farm Size	Continuous	Farm size (hectares)
Extension Services	Continuous	Number of times the respondent had access to extension services
Off-farm Activities	Dummy	Engagement in off-farm activities 0 = No, 1 = yes
Livestock	Dummy	Livestock ownership 0 = No, 1 = yes
FBO	Dummy	Farmer based organization membership 0 = No, 1 = yes
District	Dummy	0 = Mion, 1 = West Mamprusi
Credit Access	Dummy	Access to credit 0 = No, 1 = yes
Distance to Market	Continuous	Distance from home to the nearest agricultural market (in km)
Size of land owned	Continuous	Size of land owned (in hectares)
Hired Labour	Continuous	Number of man-days hired during 2014 cropping season
Irrigation	Dummy	Practice of irrigation 0 = No, 1 = yes
Risk attitude	Continuous	Degree of Risk attitude
Discount Factor	Dummy	1=preference for present , 0 otherwise

Source: Author

3.4. Measuring the impact of Jatropha Adoption on Total Crop Income of Farmers

This section uses the random utility framework as the theoretical framework underlying the impact of Jatropha adoption on crop income and the Propensity Score Matching as the estimation technique for the impact analysis.

3.4.1. Adoption of Jatropha and household crop incomes: the random utility framework

Following Hoque et al. (2015) and the equations 3.1 and 3.2, a household's decision to adopt bioenergy crop can be analyzed within a random utility framework. The outcome variable (total crops income per hectare of the household) is considered as a linear function of binary variable for bioenergy crop adoption along with a vector of some other explanatory variables (X):

$$Y_h = \lambda X_h + \gamma V_h + \mu_h \tag{3.9}$$

Where Y_h is the outcome variable, V_h is a binary variable for adoption, λ and γ are vectors of parameters to be estimated and μ is the error term. However, from Equation 3.9, since γ measures the impact of bioenergy crop adoption (treatment variable) on total crop income per hectare (outcome variable), then, households should be randomly assigned to the group of adopters or non-adopters. However, technologies are rarely randomly assigned. Instead, new technology adoption usually occurs through self-selection. In other words, it translates the fact that in Equation 3.2, μ is correlated with V or Z. Equation 3.2 which does not take into account the self-selection might lead to a biased estimation. The PSM is employed in this study in order to deal with selection bias.

3.4.2. Estimation technique for the propensity score matching (PSM)

Rosenbaum & Rubin (1983) defined the average treatment effect as follows:

$$ATE = Y_i^A - Y_i^N \tag{3.10}$$

Where Y_i^A is the total crop income per hectare of household i that has adopted and Y_i^N is the total crop income per hectare of household i that has not adopted. In order to estimate the impact from Equation 3.10, the issue is that either Y_i^A or Y_i^N is normally observed, but not both of them for each household. What is normally observed is expressed as follows:

$$Y_i = K_i Y_i^A + (1 - K_i) Y_i^N \qquad K=0, 1 \tag{3.11}$$

Where $K=1$ represents the situation when the household i adopts Jatropha, and $K=0$ is the situation when the household has not adopted Jatropha. The Average Treatment Effect can be re-specified as follows:

$$ATE = P \cdot \left[E\left(Y_i^A / K = 1\right) - E\left(Y_i^N / K = 1\right) \right] + (1 - P) \cdot \left[E\left(Y_i^N / K = 0\right) - E\left(Y_i^N / K = 0\right) \right] \tag{3.12}$$

Where P is the probability for a household to adopt Jatropha (K=1). Equation 3.12 is based on the assumption that the unobserved counterfactual of adopters if they had not adopted $E(Y_i^N / K = 1)$ can be approximated by the one of non-adopters $E(Y_i^N / K = 0)$. Without that assumption, the estimation of Equation 3.10 representing the ATE cannot be done because $E(Y_i^N / K = 1)$ is not observed. However, that procedure might highly result in a biased estimation because of the issue of selection bias. Indeed, the treated group (adopters) might not be statistically similar to the control group (non-adopters). Fortunately, the Propensity Score-Matching (PSM) approach of Rosenbaum & Rubin (1983) first reduces the pre-treatment characteristics of each household into one variable. Secondly, the PSM uses the propensity score to match households with similar characteristics. Rosenbaum & Rubin (1983) defined 'propensity score' as the conditional probability of receiving a treatment given pre-treatment characteristics:

$$p(X) \equiv \Pr\{K = 1/X\} = E\{K/X\}; \; p(X) = F\{h(X_i)\} \tag{3.13}$$

where $F\{.\}$ is a normal or logistic cumulative distribution and X a vector of pre-treatment characteristics. An estimation of the propensity of Jatropha adoption is run taking into account the restriction of the region of common support. After computing the propensity scores, the ATT effect is estimated as follows:

$$\begin{aligned} ATT &= E\{Y_i^A - Y_i^N / K = 1\} \\ &= \mathrm{E}\left[\mathrm{E}\{Y_i^A - Y_i^N / K = 1, p(X)\}\right] \\ &= \mathrm{E}\left[\mathrm{E}\{Y_i^A / K = 1, p(X)\} - E\{Y_i^N / K = 0, p(X)\} / K = 1\right] \end{aligned} \tag{3.14}$$

The Average Treatment effect of the Treated (ATT) is performed using a single matching algorithm named: Nearest Neighbor Matching with replacement. The quality of the matching is undertaken using a balance test called the mean absolute standardized bias. For each variable, the mean standardized difference is computed before and after matching as follows:

$$B(X) = 100 \frac{\overline{X_T} - \overline{X_C}}{\sqrt{\frac{V_T(X) + V_C(X)}{2}}} \tag{3.15}$$

Where $\overline{X_T}$ and $\overline{X_C}$ are the sample means for the treated and control groups, $V_T(X)$ and $V_C(X)$ are the associated sample variances (Lee, 2006). The bias reduction can be generated as follows:

$$BR = 100\left(1 - \frac{B_{after}}{B_{before}}\right) \tag{3.16}$$

Rosenbaum & Rubin (1985) recommended that the mean standardized bias after matching greater than 20% is perceived as an indicator of failed matching. In addition, according to Sianesi (2004) the balance test can be done comparing the pseudo R^2 and p-values from the propensity scores estimated before and after matching. After matching, there should not be any systematic differences in the distribution of covariates between adopters and non-adopters. As a result, the pseudo R^2 should be low. The test should be rejected after matching and not before.

3.4.3. Variable description for the impact of Jatropha adoption on total crop income of farmers and their justification

The dependent variable is the probability of farmer's participation in Jatropha cultivation. It is a binary choice variable taking the value of 1 if the farmer grows Jatropha or 0 otherwise.

The outcome variable is the total crop incomes per hectare of the household

The total household crop income per hectare includes income from food crops such as maize, cassava, rice, okro, millet, groundnut, cowpea, sorghum, tomato, yam, bean, cotton, soyabean and Jatropha. It is obtained by firstly multiplying the quantity produced of each crop grown of the household by its price and secondly summing all the crop incomes. Thirdly, the total crop income has been divided by the total area cultivated size in hectares

The independent variables are the same as those influencing Jatropha adoption (See section 3.3.3). The expected sign on the coefficient of each variable is also the same.

3.5. Farmers' Preferences for Contracts on Jatropha Production

This section provides the design of the discrete choice experiment, an analytical framework and the econometric model used to analyze farmers' preferences for contracts to produce Jatropha in Northern Ghana.

3.5.1. Design of the discrete choice experiment

Step one: Identification of attributes

A set of contract attributes were identified following discussions with experts in the area, focus group discussions and available literature on contract preferences. Four contract attributes were selected: price setting, nature of contract, support from the buyer and renegotiation option.

Step two: Definition of levels

Since there is no market for Jatropha in all Districts, in order to obtain the price of Jatropha per kilogram harvested, a convenience sampling of 30 farmers who had at least sold their Jatropha seeds once was undertaken. Bearing in mind the need to minimize hypothetical bias, the convenience sampled farmers were informed that bioenergy policy on Jatropha could not be properly designed without a realistic picture of what is happening on the field. They were then asked to state the different prices at which they had ever sold a kilogram of Jatropha seeds. The responses were used to generate three ranges of price for a kilogram of Jatropha harvested: GH₵ 0.5, GH₵ 1 and GH₵ 1.5 per kilogram of harvested Jatropha to be used for the final survey.

The attribute "nature of contract" had two (2) levels namely: Written Contract and Verbal contract. The nature of a contract influence risk management for farmers. The inclusion of this attribute was informed by Interis & Cordero-salas (2016), Abebe et al. (2013) and Barrett et al. (2012).

The attribute "Support from the buyer" had four (4) levels, namely: "Seeds-Technical Training-Fertilizers & Pesticides", "Seeds-Technical Training Only", "Seeds-Fertilizers

& Pesticides Only" and "Seeds Only". The inclusion of this attribute was also informed by Interis & Cordero-salas (2016) and Abebe et al. (2013).

The attribute "Renegotiation option" had two (2) levels: Yes and No. The inclusion of this attribute was informed by Cembalo et al. (2014) giving a possibility for the contract to be renegotiated before its end. Table 3.3 shows the summary of the attributes, levels, and descriptions used in the survey.

Table 3.3: Contract attributes and levels

Attributes	Levels	Description
Nature of contract	Written	**Written:** written document that serves as a proof to enforce the agreement by a third-party (courts or the village chief).
	Verbal (omitted base category)	**Verbal:** Informal agreement that may be difficult to enforce by a third-party
Price agreement	GH₵ 0.5, GH₵ 1 GH₵ 1.5	Price (Ghana cedis) per kilogram of Jatropha harvested
Support from buyer	Seeds, Technical training, Fertilizers & Pesticides	The buyer is committed to provide the farmer with inputs and technical training.
	Seeds and technical training Only	
	Seeds, Fertilizers & Pesticides Only	
	Seeds Only (omitted base category)	
Renegotiation option	Yes	**Yes**: Presence of an option to renegotiate the contract terms before the end.
	No (omitted base category)	**No**: absence of an option to renegotiate the contract terms before the end

Source: Author

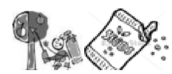
Step three: Experimental design

The full factorial design consists of $2^2 \times 3^1 \times 4^1 = 48$ possible alternatives combinations. In order to reduce this number, a fractional factorial design was implemented. Using the orthogonal design facility in SPSS, the full factorial design generated 16 alternatives which were paired into 8 choice sets (See Appendix E).

Step four: Construction of questionnaire and data collection

The interview of each respondent started with a short introduction on Jatropha, followed by an example used for illustration. The eight choice sets were randomly assigned to farmers. Pictures were used to better describe the alternatives to the respondents. The respondents were asked to choose their most preferred contract alternative within each set. Each choice set contained two contract alternatives with varying levels of nature of contract, price, support from the buyer and renegotiation option and an opt-out contract or status quo (no contract). Table 3.4 shows an example of choice set scenario as presented to the respondent. The questionnaire has been administered through well trained enumerators speaking the local languages. A pretest has been performed before administered the final questionnaire. The questionnaire also included a section on socioeconomic characteristics of respondents.

Table 3.4: Typical choice set scenario

	Contract type	Price Setting	Support from buyer	Renegotiation option	I would choose:
Contract A	Written Contract 	GH₵ 1/kg	Seed, Fertilizers &Pesticides Only 	No	○
Contract B	No Written Contract 	GH₵ 1.5/kg	Seed, Technical training, Fertilizers&Pesticidess 	No	○
No Contract	I would not grow Jatropha under the offered contracts and would maintain my current crop mix				○

Source: Author

Step five: Data analysis

Choice experiment data have been entered using Excel. The data have been transferred to and analyzed using LIMDEP/NLOGIT 4.0 software. A Random Parameter Logit model has been employed. Each respondent made eight choices, the estimation is coded to treat each respondent as a panel, thus making the estimation one of panel RPL. The price attribute is assumed to follow a log-normal distribution with zero variance (Carson & Czajkowski, 2013). Consequently, the sign of the price attribute were reversed prior to model estimation (Carson & Czajkowski, 2013; Hensher & Greene, 2003). The constant and attribute coefficients (except price) are randomized and assumed following a normal distribution. Given the panel nature of the data (each farmer made eight choices), the study constrained the individual-specific attribute coefficients to be equal across choice observations for each farmer. In addition to the attributes, a number of covariates are included in the model as nonrandom parameters. These covariates are binary variables for choice question order, net revenue of the crop most likely to be substituted with Jatropha and variance on net revenue. Simulations are required in Random Parameter Models in order to provide parameter approximations. All the models are estimated using simulated maximum likelihood with 500 Halton draws (Train, 2002).

3.5.2. Analytical framework: mean variance utility

The exponential utility (EU) function that uses the Constant absolute risk aversion coefficient has been used as an objective function for analyzing decisions under risk (Spiegel, 2013). Consequently, let's assume that individual preferences exhibit Constant Absolute Risk Aversion (CARA) under the expected utility maximization usually modeled through an exponential utility function of his/her revenue such that:

$$U(R) = -e^{-\delta R}, \delta \succ 0 \quad (3.17)$$

Where δ is the Arrow-Pratt risk aversion coefficient;

Taking the first and second derivatives of Equation 3.17, the result is:

$$U^{/}(R) = \delta e^{-\delta R} \succ 0, \qquad U^{//}(R) = -\delta^{2} e^{-\delta R} \prec 0 \quad (3.18)$$

Equation 3.18 holds since that utility is increasing and concave in revenue, R. Here, concavity reflects risk aversion. In addition, it can also be noted that the Arrow – Pratt absolute risk aversion coefficient is given by:

$$\delta = -\frac{U^{//}(R)}{U^{/}(R)} \quad (3.19)$$

Equation 3.19 means that the larger δ is, the more risk averse the farmer is. Now, let's assume that revenue (R) is distributed normally with mean, μ and standard deviation, σ then, the density of R is:

$$f(R)=\frac{e^{\frac{-(R-\mu)^2}{2\sigma^2}}}{\sigma\sqrt{2\pi}} \tag{3.20}$$

Hence, the expected utility is:

$$\begin{aligned} EU(R) &= \frac{1}{\sigma\sqrt{2\pi}}\int_{-\infty}^{+\infty} -e^{-\delta R}e^{\frac{-(R-\mu)^2}{2\sigma^2}}dR \\ &= \frac{1}{\sigma\sqrt{2\pi}}\int_{-\infty}^{+\infty} -e^{-\left(\delta R+\frac{(R-\mu)^2}{2\sigma^2}\right)}dR \end{aligned} \tag{3.21}$$

Let's rearrange the exponent in Equation 3.21 so as to group terms that depend on R and terms that do not depend on R, it results:

$$\delta R+\frac{(R-\mu)^2}{2\sigma^2}=\frac{(R-\mu+\delta\sigma^2)^2}{2\sigma^2}+\delta\left(\mu-\frac{\delta\sigma^2}{2}\right) \tag{3.22}$$

The proof of Equation 3.22 is found in Appendix B.

Substituting Equation 3.22 into Equation 3.21, it gives:

$$EU(R)=-\frac{e^{-\delta\left(\mu-\frac{\delta\sigma^2}{2}\right)}}{\sigma\sqrt{2\pi}}\int_{-\infty}^{+\infty} e^{-\frac{(R-\mu+\delta\sigma^2)^2}{2\sigma^2}}dR \tag{3.23}$$

For all $U^{//}$ it gives:

$$\frac{1}{\sigma\sqrt{2\pi}}\int_{-\infty}^{+\infty} e^{-\left(\frac{(R-\mu^{/})^2}{2\sigma^2}\right)}dR=1 \tag{3.24}$$

because the left hand side of the Equation 3.24 is the area under the density function over the entire support when the mean is $\mu^{/}$ and the standard deviation γ. For any $\mu^{/}$, including $\mu^{/}=\mu-\delta\gamma^2$ it gives:

$$EU(R)=-e^{-\delta\left(\mu-\frac{\delta\sigma^2}{2}\right)} \tag{3.25}$$

Where μ is the mean revenue and σ^2 the variance associated with the revenue. The utility function in Equation 3.25 is monotone increasing in $\mu - \frac{\delta\sigma^2}{2}$. Indeed, the choice variable of interest for the farmer only affects the mean and variance of the agent's revenue. Then, maximizing the expected utility is equivalent to maximizing $\mu - \frac{\delta\sigma^2}{2}$. Then, the individual' expected utility which is a linear function of his mean revenue and the variance of his revenue is given by:

$$U = \mu - \frac{1}{2}\delta\sigma^2 \qquad (3.26)$$

3.5.3. Method of choice data analysis: the random parameter logit (RPL)

Random Parameter Logit model is adequately flexible to approximate any random utility model under a variety of different behavioral specifications (McFadden & Train, 2000; Train, 2002). The study adapts the above mean-variance utility framework which is consistent with the expected utility maximization to allow preference heterogeneity using a Random Parameter Logit model. By including the alternative-specific constant and control variables (attributes variables, choice-question order variables and covariates constant into the utility function (Equation 3.26), the utility function that an individual i derives from choosing an alternative j can be re-specified as:

$$U_{ij} = \alpha_0 + \eta_i + \alpha_\mu \mu - \left(\alpha_{RA} RA + \alpha_{RS} RS\right)\frac{\delta_i \sigma_i^2}{2} + \beta' X_{ij} + v_i' X_{ij} + \gamma' Q + \varepsilon_{ij} \qquad (3.27)$$

Where: α_0 is the alternative-specific constant taking into account the preference for the no-contract option (status-quo); η_i is the associated random term; RS and RA are binary indicators for whether a farmer is categorized as risk-seeking or risk-averse, respectively;

a risk neutral farmer has been considered as an omitted base category. μ, δ and σ are respectively the mean, risk aversion coefficient and the standard deviation. α_{μ}, α_{RA} and α_{RS} are respectively associated fixed coefficients to be estimated; **X** is a vector of alternative-specific contract attributes (nature of contract, contract price setting, support from the buyer and renegotiation option); β are the associated coefficients to be estimated; v_i are individual-specific standard deviation parameters; Q is a vector of binary indicators to control for choice question order with the associated fixed parameters γ ; In fact, eight choice sets were randomly presented to farmers. ε_{ij} [6]is identically and independently distributed (iid) following a Gumbel distribution. The estimated model will be used to estimate farmer willingness to accept each contract attribute.

3.5.4. Model variations of the random parameter logit

Four (4) alternative models were specified: i) An attribute-only model assuming homogeneity of preferences, ii) a model interacting specific individual characteristics with contract attributes in order to account for individual heterogeneity (Wiktor Adamowicz, Swait, Boxall, Louviere, & Williams, 1997), iii) a model incorporating respondent-specific information on net revenue of the crop most likely to be substituted with Jatropha, variance on net revenue and self-assessment risk preference elicitation and iv) a model incorporating respondent-specific information on net revenue of the crop most likely to be substituted with Jatropha, variance on net revenue and psychometric risk preference elicitation.

[6] This non-observable term accounts for all unobserved sources likely to influence utility. In choice analysis, this term is assumed to follows a Gumbel distribution (type 1 extreme value) (Louviere et al., 2000)

i. Attribute-only model assuming homogeneity of preferences

This model assumes that preferences are homogeneous across individuals, in order words that individuals face the same opportunity costs. It also assumes that parameters of both alternative-specific constant and attributes variables are random. Parameters of choice-question order variables are assumed fixed (non-random).

ii. Model with interaction allowing to find sources of heterogeneity

This model allows for socio-economic variables interaction with the attributes of the alternatives in order to find possible sources of heterogeneity. The variable District is interacted with the attributes written contract, renegotiation option and support of the buyer in form of "seeds, technical training, fertilizers and pesticides". The variable gender is interacted with the attribute support of the buyer in form of "seeds and technical training", the variable Jatropha adoption status is interacted with the attribute support of the buyer in form of "seeds, technical training, fertilizers and pesticides". In addition to these variables added as covariates, parameters of both alternative-specific constant and attributes variables are assumed random. Choice-question order variables are assumed non-random (fixed).

iii. Two models incorporating subjective risk perceptions (subjective mean and variance associated with crop yields) and risk preferences (self-assessment and psychometric risk elicitation) to allow for heterogeneity of preferences

The homogeneity of preferences might not always hold especially with farmers producing a variety of crops with different net revenues, and facing different risks. This model incorporates risk perceptions, risk preferences and choice-question order as non-random variables. Parameters of both alternative-specific constant and attributes variables are assumed random. Parameters of choice-question order variables are assumed fixed (non-random). Two models are developed depending on the risk preference elicitation method used. One uses self-assessment risk elicitation approach while the other uses the psychometric risk preferences elicitation method.

The study tests these models against the "base" model with homogeneous status quo alternative in order to find out whether there is significant model improvement. The model improvement is tested using the likelihood-ratio test and AIC (Akaike In formation Criterion)

3.5.5. Random parameter Logit (RPL) and willingness to accept (WTA) contract

Following Bliemer & Rose (2013), in case of a linear utility function, the willingness to accept (WTA) for contract attribute k is the ratio of the estimated parameter for non-monetary contract attributes k (β_k) and price parameter (β_p) is defined as:

$$WTA_k = \frac{\beta_k}{\beta_p} \tag{3.28}$$

The WTA then represents the monetary equivalent of increasing the attribute value by one unit. It is also the marginal rate of substitution between the monetary value of the contract and the contract attribute in question. In the context of this study, the farmers' willingness to accept (WTA) is the price per kilogram of Jatropha harvested for changes in attributes of a contract. However, in the case of a RPL, both parameters β_k and β_p follow certain distributions. Both estimated contract attribute means and standard deviations are functions of estimated parameters. Following Bliemer & Rose (2013), any random parameter in the RPL model can be expressed as:

$$\beta_k = \beta_k\left(z_k \middle| \theta_k\right) \tag{3.29}$$

Where the random parameter β_k follows a probability distribution with a vector of parameters θ_k and standard probability distribution z_k. In this study, β_k is assumed to follow a normal distribution while β_p follows a lognormal distribution. Equation 3.29 can be rewritten as: $\beta_k = \mu_k + \sigma_k z_k$ where z_k follows a normal distribution $N(0,1)$. In case all random parameters are expressed as a function of their respective mean, standard deviation and assumed distribution, the WTA for any contract attribute k is expressed as:

$$WTA_k = \frac{\beta_k}{\beta_p} = \frac{\mu_k + \sigma_k z_k}{\exp\left(\mu_p + \sigma_p z_p\right)} \tag{3.30}$$

where μ represents the estimated mean and σ the estimated standard deviation for contract attribute and price. The WTA for contract attribute is a function of contract attribute parameters $\theta_k(\mu_k, \sigma_k)$, price parameter $\theta_p(\mu_p, \sigma_p)$, normally distributed random variables z_k and log-normally distributed random price variable z_p.

3.5.6. Confidence intervals for willingness to accept (WTA) contract attribute in the random parameter Logit (RPL): the delta method

Following Bliemer & Rose (2013) in applying the Delta method to Equation 3.30, it results:

$$\hat{WTA}_k\left(z_{k,}z_p\right) \xrightarrow{D} N\left(WTA_k, \begin{pmatrix} \nabla_{\theta_k} WTA_k \\ \nabla_{\theta_p} WTA_k \\ \nabla_{z_k} WTA_k \\ \nabla_{z_p} WTA_k \end{pmatrix}^T \begin{pmatrix} \Omega_{\theta_{kp}} & 0 \\ 0 & diag(1,\ldots,1) \end{pmatrix} \begin{pmatrix} \nabla_{\theta_k} WTA \\ \nabla_{\theta_p} WTA_k \\ \nabla_{z_k} WTA_k \\ \nabla_{z_p} WTA_k \end{pmatrix}\right) \tag{3.31}$$

Where $\nabla_{\theta_k} WTA_k$ and $\nabla_{\theta_p} WTA_k$ are the Jacobians of WTA with respect to θ_k and θ_p, $\nabla_{z_k} WTA_k$ and $\nabla_{z_p} WTA_k$ are the Jacobians of WTA with respect to z_k and z_p. $\Omega_{\theta_{kp}}$ is the variance covariance matrix of the distributional parameters θ_k and θ_p. The Jacobians are calculated as:

$$
\begin{aligned}
\nabla_{\theta_k} WTA_k &= \nabla_{\theta_k}\left(\frac{\beta_k(z_k|\theta_k)}{\beta_p(z_p|\theta_p)}\right) = \frac{1}{\beta_p}\nabla_{\theta_k}\beta_k \\
\nabla_{\theta_p} WTA_k &= \nabla_{\theta_p}\left(\frac{\beta_k(z_k|\theta_k)}{\beta_p(z_p|\theta_p)}\right) = -\frac{\beta_k}{\beta_p^2}\nabla_{\theta_p}\beta_p = -\frac{WTA_k}{\beta_p}\nabla_{\theta_p}\beta_p \\
\nabla_{z_k} WTA_k &= \nabla_{\theta_p}\left(\frac{\beta_k(z_k|\theta_k)}{\beta_p(z_p|\theta_p)}\right) = \frac{1}{\beta_p}\nabla_{z_k}\beta_k \\
\nabla_{z_p} WTA_k &= \nabla_{\theta_p}\left(\frac{\beta_k(z_k|\theta_k)}{\beta_p(z_p|\theta_p)}\right) = -\frac{\beta_k}{\beta_p^2}\nabla_{z_p}\beta_p = -\frac{WTA_k}{\beta_p}\nabla_{z_p}\beta_p
\end{aligned}
\tag{3.32}
$$

Replacing Equation 3.32 in Equation 3.31, it results:

$$
\hat{WTA}_k(z_k, z_p) \xrightarrow{D} N\left(WTA_k, \frac{1}{\beta_p^2}\begin{pmatrix}\nabla_{\theta_k}\beta_k \\ -WTA_k\nabla_{\theta_p}\beta_p \\ \nabla_{z_k}\beta_k \\ -WTA_k\nabla_{z_p}\beta_p\end{pmatrix}^T \begin{pmatrix}\Omega_{\theta_{kp}} & 0 \\ 0 & diag(1,\ldots,1)\end{pmatrix}\begin{pmatrix}\nabla_{\theta_k}\beta_k \\ -WTA_k\nabla_{\theta_p}\beta_p \\ \nabla_{z_k}\beta_k \\ -WTA_k\nabla_{z_p}\beta_p\end{pmatrix}\right) \tag{3.33}
$$

For any random draw of z_k and z_p, the expected WTA estimate $(\hat{WTA}_k)$ is defined as:

$$
\hat{WTA}_k = \iint_{z_k z_p} \hat{WTA}_k(z_k, z_p)\, dF_k(z_k)\, dF_p(z_p) \tag{3.34}
$$

Where $F_k(z_k)$ and $F_p(z_p)$ are cumulative distribution functions of the standard distributed z_k and z_p.The unconditional mean estimate of WTA can be approximated by Monte Carlo simulation:

$$
\hat{WTA}_k \approx \frac{1}{R}\sum_{r=1}^{R} \hat{WTA}_k(z_k^r, z_p^r) \tag{3.35}
$$

Where $r = 1,\ldots,R$ and $\left(z_k^r, z_p^r\right)$ are random draws from the normal and log normal distributions $F_k\left(z_k\right)$ and $F_p\left(z_p\right)$. Since $\hat{WTA}_k\left(z_k^r, z_p^r\right)$ is asymptotically normally distributed then, $\hat{WTA}_k$ is also normally distributed in the limit with the following simulated standard errors:

$$se\left(\hat{WTA}_k\right) \approx \frac{1}{R}\sum_{r=1}^{R}\left(\frac{1}{\left(\beta_p^r\left(z_p^r\right)\right)^2}\begin{pmatrix}\nabla_{\theta_k}\beta_k^r \\ -WTA_k^r\nabla_{\theta_p}\beta_p^r \\ \nabla_{z_k}\beta_k^r \\ -WTA_k^r\nabla_{z_p}\beta_p^r\end{pmatrix}^T \begin{pmatrix}\Omega_{\theta_{kp}} & 0 \\ 0 & diag\left(1,\ldots,1\right)\end{pmatrix}\begin{pmatrix}\nabla_{\theta_k}\beta_k \\ -WTA_k^r\nabla_{\theta_p}\beta_p^r \\ \nabla_{z_k}\beta_k^r \\ -WTA_k^r\nabla_{z_p}\beta_p^r\end{pmatrix}\right) \tag{3.36}$$

Where $WTA_k^r\left(z_k^r, z_p^r\right) = -\dfrac{\mu_k + \sigma_k z_k^r}{\exp\left(\mu_p + \sigma_p z_p^r\right)}$

After the asymptotic standard error has been calculated in Equation 3.36, the confidence interval of the expected WTA estimate is determined as follow:

$$\left(\hat{WTA}_k - t_{1-\alpha/2}se\left(\hat{WTA}_k\right), \hat{WTA}_k + t_{1-\alpha/2}se\left(\hat{WTA}_k\right)\right) \tag{3.37}$$

3.5.7. Variable description for farmers' preferences for contracts on Jatropha production

Dependent variable: Farmer choice taking the value 1 if a farmer chooses one of the contract alternatives (contract A, B,…,P) or the opt-out option (No contract).

Independent variables

Contract attributes: The contract attributes were coded according to their levels

Nature of contract: This attribute enters the utility function as a binary variable taking the value 1 if the contract is in the written form and 0 if it is oral. It is expected that farmers would prefer a written contract because most of the time the terms of the contracts agreement are able to be enforced in the courts. Written contracts set out all the details or terms agreed on between parties.

Support from the buyer: The levels of this attributes are: "Seeds, technical training, fertilizers and pesticides only", "Seeds, fertilizers and pesticides only", "Seeds and technical training only" and "Seeds Only". Each level is coded as a dummy 1 if the level is present in the contract alternative or 0 otherwise. It is expected that each level of this attribute has a positive influence on the choice of contract. A positive coefficient is an indicator of preference for contracts with the level of this attribute.

Price setting: It takes the values GH₵ 0.5, GH₵ 1 and GH₵ 1.5. It is the price per kilogram of harvested Jatropha. The expected sign is positive. Farmers would place more values on contracts providing higher price offered.

Renegotiation option: It takes the value 1 if the option to renegotiate the contract terms before the end of the contract and 0 if it is not possible. Farmers would prefer to renegotiate the contract terms if it is possible in case the contracts terms are not advantageous for them.

Interaction variables:

Gender: It is a dummy variable taking the value 1 for female and 0 for male.

Gender*Seeds and technical trainings: It is expected that women would more prefer contracts providing seeds and technical trainings in order to improve their cultivation practices than men. Women have less access to education and trainings in agriculture compared to men.

Adopter: It is a binary variable taking the value 1 if the farmer is growing Jatropha and 0 otherwise

Adopter*Seeds, technical training, fertilizers and pesticides: It is expected that Jatropha adopters would more prefer to enter into a contract that provides full support such as seeds, technical trainings, fertilizers and pesticides. An adopter is expected to have experience in Jatropha cultivation and thus required all these forms of support.The expected sign is positive.

District: It is a dummy variable taking the value 1 for West Mamprusi and 0 for Mion.

District*Written contract: It is expected that farmers in West Mamprusi District would prefer written contract form. The expected sign is positive.

District*Renegotiation option: It is expected that farmers in West Mamprusi District would prefer the option of renegotiating the contract terms before the end. The expected sign is positive.

District*Seeds, technical training, fertilizers and pesticides: It is expected that farmers in West Mamprusi District would prefer to receive full support from the buyer in terms of Seeds, technical training, fertilizers and pesticides for a better output. The expected sign is positive.

Risk variables: The risk variables are two dummy variables each taking the value 1 if the farmer is risk averse/lover and 0 otherwise. It is expected that a risk averse farmer would not choose to adopt Jatropha since the returns from investment commences after the third year where the harvest is possible. He would prefer investing in annual crop.

Risk preferences of farmers are measured in two alternative ways: self-assessment and psychometric risk attitude measurements.

Self-assessment risk attitude:

Following Dohmen et al. (2012), the self-assessment risk attitude are measured using the exact wording: *How do you see yourself: Are you a person who takes risk or do you try to avoid risks? Please self-grade your choice (ranging between 0-10), where the grades run from 0: "not at all prepared to take risk" to 10: "very much prepared to take risk".*

The above question was asked for several domains: general, agriculture, finance, education and health. The study used the reported choice for the domain "agriculture". A farmer was categorized as a risk averse if he/she chooses a grade less than 5, risk taker if he/she chooses a grade greater than 5 and risk neutral if he/she chooses a grade equal to 5.

Psychometric risk attitude

The attitudinal scale approach or psychometric risk attitude approach is a technique which consists of defining a scale of statements that reflect subject's attitude toward risk and establishing a score reflecting a quantitative measurement of the attitude. Eliciting individuals' attitudes with a scale has been implemented for various attributes (referred to as constructs or underlying latent variables in the psychometric literature). Examples include investment risk (Hube, 1998) self-esteem (McIver & Carmines, 1981), locus of control issues such as work and health (Spector, 1992), depression and traits (DeVellis, 1991) and farming (Bard & Barry, 2000). The scales consist of either questions or statements (called items) that correspond to or are influenced by the social-psychological attribute. Respondents rate each item, thus conveying their attitudes toward the underlying variable. The respondents' ratings of the multiple items are summed to yield a score for the individual. The score can then be scaled for comparison to other respondents' scores (Bard & Barry, 2000). To develop a psychometric items, first a large pool of items or questions that reflect attitudes toward risk are generated (depending on the underlying activities the subjects are involved in, the context of the study, etc.). Next, these items or question are tested for clarity and appropriateness in focus groups discussions or subsample of the population. Based on the feedback from the subjects, some items were eliminated, others modified, and additional items added. The finalized items or question were then administrated to the sample subjects. In the final based on the responses of the subjects, items are validated (the empirical validation can be based on construct validity, convergent validity, and exploratory analysis) and only validated items included in the analysis to determine attitude score. Once the items were validated they can be replicated in similar studies. In this study, items validated from a study conducted by Bard & Barry (2000) were contextualized and used. The following 10 statements are generated from the Bard et al. (2000) study.

A Likert scale consisting of five levels of agreement ranging from strongly agree, agree, neutral, disagree to strongly disagree. The scores on all items have been summed, ranging from zero to 50. A farmer was categorized as a risk averse if his/her summed score is less than 25, risk taker if its summed score is greater than 25; risk neutral if his/her summed score is equal to 25. The exact wordings were:

Please answer the 10 following statements with respect to your activities.

I do not rely only on my production

I complement my farm income with off-farm income

I have some of my assets in liquid (cash) form

By my experience I engage in only less risky enterprise

I obtain marketing information before sales of my farm produce

I am never among the first producers in my area to adopt new technology

Off-farm investments are important sources of income for me.

I always store my production to anticipate good price

I invest a lot in my farm (buying improved seeds and fertilizers…)

More than 50% of my farm productions is for my own consumption

Net revenue and variance

Net revenue: The study involved farmers producing diverse crops with diverse levels of revenue and risk. Consequently, they were willing to substitute different crops (maize, rice, sorghum, etc.) for production of Jatropha. In order to account for these differences and determine a common measure for status-quo, the difference between the expected revenue per hectare from the production of the current crop they were most likely to replace Jatropha and the expected revenue from Jatropha was used as net revenue.

Expected revenue per hectare from the production of the current crop most likely to be substituted with Jatropha based on subjective judgment

Using information on farmers' expectations of yield and prices of their current crop, the expected revenue per hectare based on the plot size information of the current crop was calculated. As proposed by Griffiths, Anderson, & Hamal (1987) for subjective yield distribution elicitation, a triangular distribution was assumed. In addition, the triangular distribution is useful when based on subjective judgment, minimum, maximum and most likely values are known (Mishra, 2002).

The subjective questions asked to the respondents were:

Which of your current crops is most likely to be substituted with Jatropha?

What yield do you consider most likely for your current crop during the next harvest period?

What do you expect will be your lowest yield during the next harvest period?

What do you expect will be your highest yield likely during the next harvest period?

What price do you anticipate to be the most likely "current crop" price during the next harvest period?

What price do you anticipate to be the lowest possible "current crop" price during the next harvest period?

What price do you anticipate to be the highest possible "current crop" price during the next harvest period?

The mean revenue μ and variance σ^2 were calculated based on a triangular distribution (Johnson, 2002; Mishra, 2002; Williams, 1992).

$$\mu = (1/3)(L + M + H) \tag{3.17}$$

$$\sigma^2 = (1/18)\left[(H - L)^2 + (M - L)(M - H)\right] \tag{3.18}$$

Where: L, M and H are respectively the lowest, most likely and highest revenue of the crop most likely to be substituted with Jatropha. Each of these revenues are obtained by multiplying the lowest yield with the lowest price, most likely yield with most likely price and highest yield with highest price.

Expected revenue per hectare for Jatropha production

Data on Jatropha yields are scarce (FAO, 2010). Previously reported high yields relied on inconsistent data and were due to measurement extrapolation (Jongschaap, Corré, Bindraban, & Brandenburg, 2007). Jatropha seed yields are reported to be between 0.4-12 tonnes per hectare (Openshaw, 2000). Following discussion with local experts and focus group discussions with farmers, an expected price of GH₵ 1 per kilogram of harvested Jatropha and expected yield of 2 tonnes dry seeds per ha per year were assumed. This information was made known to the respondents as part of the survey in September 2015. However, Jatropha being a perennial crop, can take at least three years to reach full harvest potential and suggests that farmers who agree to grow it would have to wait until the end of the third year for a marketable harvest. In effect, for a ten-year contract, producers would actually receive payment in only eight of those years. Consequently, the expected revenue per hectare from Jatropha production was calculated as follows: GH₵ 1 per kg x 2 x 1000kg x 8 years /10 years = GH₵ 1600/ha.

Finally, the expected revenue difference was obtained by subtracting the expected revenue per hectare for producing Jatropha under a ten year contract from the expected revenue per hectare of the current crop most likely to be substituted with Jatropha.

An increase of net revenue (difference between the expected revenue per hectare from the production of the current crop most likely to be replaced with Jatropha and the expected revenue from Jatropha) is expected to reduce the likelihood of accepting a contract to produce Jatropha.

Variance: The variance of the revenue of the crop most likely to be substituted by Jatropha

If the variance of the revenue of the current crop most likely to be substituted with Jatropha increases, then cultivating that crop becomes more risky. In this case, a risk averse farmer would accept a contract to produce Jatropha. It is expected that an increase in the variance of the revenue of the current crop most likely to be substituted with Jatropha leads to an increase in the likelihood of a risk-averse farmer to accept contract to produce Jatropha.

3.6. Sampling Method and Study Area

3.6.1. Sampling Method

Data used in this study were collected from 400 farmers in Northern Ghana using a questionnaire in September 2015.

Focus group discussions consisted of meeting with community leaders and some Jatropha farmers in each District to gather preliminary information: Number of Jatropha growers in the communities, the size of their Jatropha plot, the contractual arrangement with out-growers and prices of Jatropha per kilogram ever sold. The estimated number of Jatropha farmers in these two Districts was 344 farmers (256 farmers in West Mamprusi District and 88 farmers in Mion District). This information was used to calculate the minimum sample size.

Yamane's formula of sample size is used (Yamane, 1967):

$n = \frac{N}{1+N(e)^2}$ Where n is the sample size, N is the population size, e is the error term.

Assuming an error of 5% and a confidence interval of 95%, the following is obtained: $n = \frac{344}{1+344(0.05)^2} = 184.94$. The number of Jatropha adopters was increased to 200.

A stratified random sampling technique consisting of dividing the population in groups called strata and proceeding with a simple randomization was used to select the list of Jatropha farmers to be surveyed. The stratification was done at the District level. The first stage involved purposive selection of Jatropha growing Districts in Northern Ghana. These are West Mamprusi District and Mion District. 120 Jatropha farmers were randomly selected in West Mamprusi District and 80 in Mion District in order to have a fair representation of farmers in both Districts based on the preliminary study.

The study needed a counterfactual to evaluate the effect of Jatropha farming adoption on key outcomes such as income. An equal sample size of 200 non-Jatropha farmers was used. The procedure to survey the non-Jatropha farmers was as follows: In each community where the Jatropha farmers were surveyed the equal number of non-Jatropha farmers was also surveyed. To choose a non-Jatropha farmer, a sample list of some non-Jatropha farmers in the community was collected from community leaders. A random list with 3 backup was then formed for each community to survey the non-Jatropha farmers. Table 3.5 shows the distribution of respondents per District and community.

Table 3.5: Distribution of respondents per District and community

District	Community	Adopters	Non-adopters
West Mamprusi District	Zagsilari	20	20
	Nasia	19	19
	Boamasa	20	20
	Janga	20	20
	Wungu	20	20
	Loagri	21	21
Mion District	Jimle	47	47
	Kpachaa	30	30
	Tuya	03	03
	Total	200	200

Source: Author

A structured questionnaire was used to collect information on: Socio economic characteristics, field crop production, data on inputs used, general information on Jatropha, expenditure and choice experiment data of farmers.

3.6.2. Study area

The information on the study area were obtained from Ghana Statistical Service (2014a) and Ghana Statistical Service (2014b).

Mion District was carved out of the Yendi Municipal Assembly due to the increasing population and to enable development reach all communities in 2012. Mion District is located in the eastern corridor of the Northern Region of Ghana between Latitude 90 – 35" North and 00 – 30" West and 00 – 15" East. The District shares boundaries with the Tamale Metropolis, Savelugu Municipal and Nanton District to the west, Yendi Municipal to the east, Nanumba North and East Gonja Districts to the south and Gushegu and Karaga Districts to the north.

The District covers a surface area of 2714.1 sq. km and has a population density of 30.1 persons per square kilometre.

The climate of the District is relatively dry, with a single rainy season that begins in May and ends in October. The amount of rainfall recorded annually varies between 750 mm and 1050 mm. The dry season starts in November and ends in March/April with maximum temperatures occurring towards the end of the dry season and minimum temperatures in December and January. The Harmattan winds, which occur during the months of December to early February, have considerable effect on the temperatures in the District, which may vary between 14˚C at night and 40˚C during the day. Humidity, which is very low, mitigates the effect of the daytime heat.

The District has vast areas of grassland, interspersed with the Guinea Savannah woodland, characterized by drought-resistant trees such as acacia, Shea and dawadawa. 90 percent of the people of the District depend on agriculture for their livelihood. Three types of agricultural activities have been identified: crop farming (98.7 percent), tree planting (0.3 percent) and livestock rearing (54.8 percent).

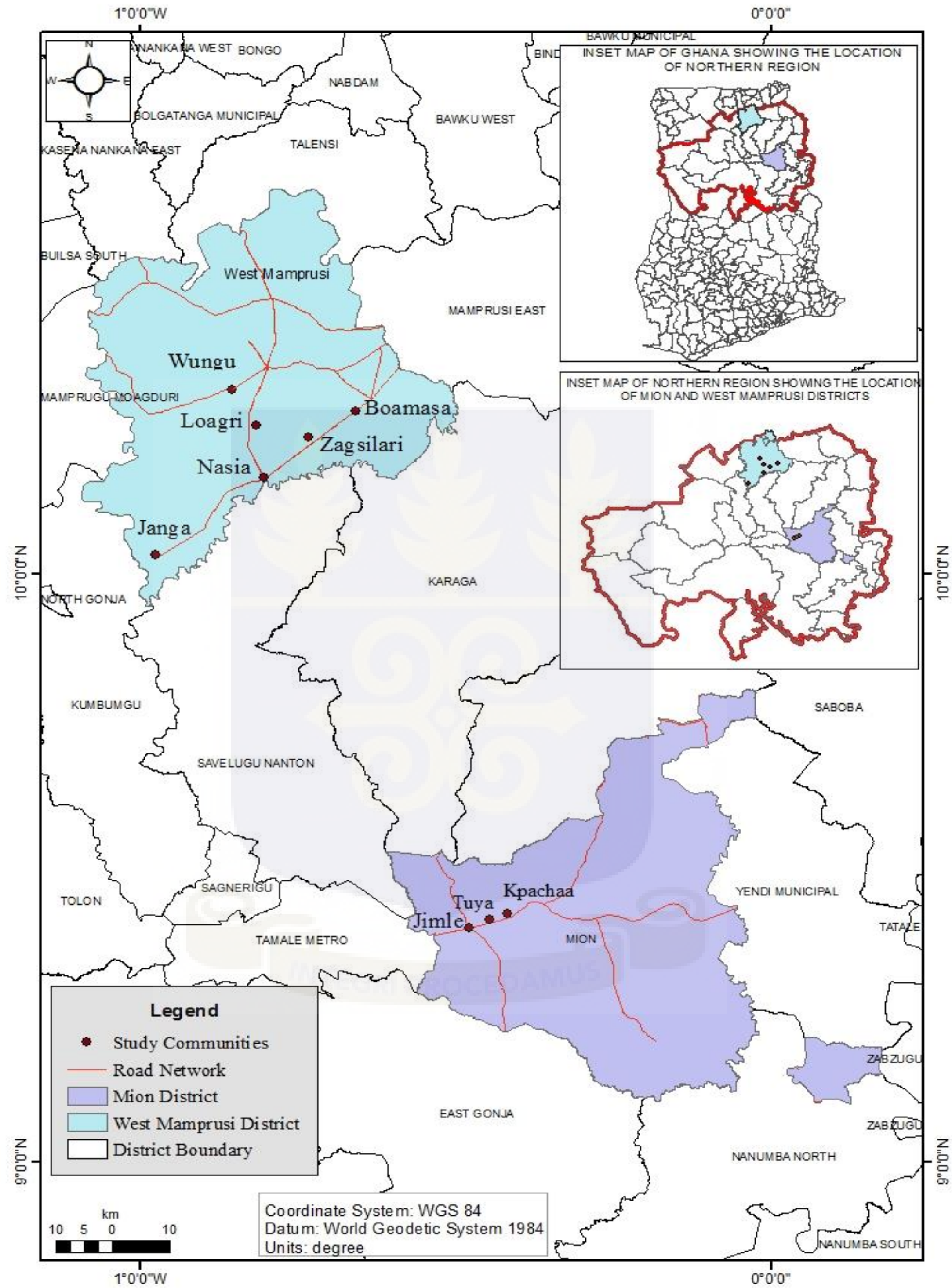
Other economic activities include smock weaving, agro-processing (Shea butter and groundnut oil extraction), meat processing, fish mongering, wholesale and retail of general goods, animal husbandry, transport and many others. These activities are on a medium and small scale basis.

BioFuel Africa Ltd established Jatropha plantation in March 2008 in three villages in the Mion District of Northern Ghana. The company first began the Jatropha project in Alipe, a village in the Central Gonja District of Northern Ghana in 2007 but met local opposition in Ghana from non-governmental agencies (NGOs), individual environmental activists and media debates on the grounds of perceived dire implications on local livelihoods and food security (Boamah, 2010).The project was abandoned in the village after a month-long operation and the company subsequently moved to a new project site in Mion District where the Jatropha plantation was established.

West Mamprusi is located roughly within longitudes 0°35’W and 1°45’W and latitude 9°55’N and 10°35’N. The total land area is 5,013 km² and shares boundaries with ten Districts and one region Upper East. The District is characterized by a single rainy season, which starts in late April with little rainfall, rising to its peak in July-August and declining sharply and coming to a complete halt in October-November. The area experiences occasional storms, which have implications for base soil erosion depending on its frequency and intensity especially when they occur at the end of the dry season. Mean annual rainfall ranges between 950mm - 1,200mm. The dry season is characterized by Hamattan winds. These winds, which blow across the Sahara desert, are warm and dry causing significantly daily temperatures and causing the soil to lose moisture rapidly. Maximum day temperatures are recorded between March-April of about 45°C while minimum night temperatures of about 12°C have been recorded in December-January. The humidity levels between April and October can be as high as 95% in the night falling to 70% in the day. Night humidity for the rest of the years ranges between 80% and 25%.

A five-year project (2009-2014) called GHAJA Project conducted on the use of Jatropha Curcas (a drought-resistant perennial species for energy production) to improve access to sustainable, affordable and more efficient energy options for rural communities in Northern Ghana was located in West Mamprusi District. Figure 3.3 shows the map of the study area.

Figure 3.3: Map of study area



Source: Author

3.7. Scope and limitations of the study

Concerning the Propensity Score Matching technique, the sample of non-adopters (200) was equal to the sample of non-adopters (200). Most of the times in adoption studies, the non-treated sample is at least one and half to two the treatment sample (Kassie et al., 2011; Shiferaw et al., 2014). This sample has limited the use of the different matching methods available to the Neighbour Matching with Replacement.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1. Introduction

This chapter reports the results and discussions of the research per specific objective. Section 4.2 presents the results and discussion of objective one. Section 4.2 presents the results and discussion of objective two. Section 4.3 presents the results and discussion of objective three. Section 4.4 presents the results and discussion of objective four.

4.2. Factors Explaining Farmers' Adoption and Land Allocation to Jatropha in Northern Ghana

4.2.1. Descriptive statistics

In Table 4.1 is presented the descriptive statistics of continuous variables used in the econometric models for the entire sample and the two sub-samples of non-adopters and adopters indicating the variable means and standard deviations. Data was collected from 400 farmers (200 adopters and 200 non-adopters). In this study an adopter is a farmer who is currently growing Jatropha in his/her field. Adopters are distinguishable in terms of household characteristics such as age, farming experience, number of visits by extension services officers and number of man-days labour hired.

On average, adopters allocate 0.5 hectare to Jatropha cultivation. The mean age of farmers interviewed was about 43 years old. There is a significant difference in the age of adopters and non-adopters. On average, adopters are 45 years old while non-adopters are 41 years old. There is no significant difference in the number of adult members in the household of both adopters and non-adopters. On average, the number of adult members in the household is 5. There is no significant difference in the years of education for farmers both adopters and non-adopters. On average, farmers spent 2 years of education. There is a significant difference in the years of farming experience at the level 5% between the two groups. On average, Jatropha adopters have been farming for about 26 years while non-adopters for about 23 years. There is no statistically difference in farm size between the two groups and the farm size is 3.75 hectares. On average, farmers owned 3.56 hectares of land. Adopters hired more labour than non-adopters There is no statistical difference in distance from the nearest agricultural market for the full sample. On average, the distance from home to the nearest agricultural market is 8.3 kilometers. There is a significant difference at the level 1% in the number of times farmers had access to extension services. Adopters had more access to extension services than non-adopters. On average, adopters had access to extension services 0.29 times compared to 0.15 for non-adopters during the 2014 cropping season.. The mean number of hired man-days for adopters is 125 compared to 79.16 man-days for non-adopters. The difference is significant at the level 5%. There is no statistical difference on the degree of risk attitude of the farmers. On average, the degree of risk attitude is 5.73.

Table 4.1: Descriptive statistics for continuous variables

Variables	Adopters		Non-Adopters		Total		t-value
	Mean	SD	Mean	SD	Mean	SD	
Jatropha land Allocation	0.50	0.02	0	0	0.25	0.01	-26.62^{***}
Age	45.13	15.25	41.06	13.76	43.09	14.65	-2.80^{***}
Number of adults	5.81	5.54	5.21	3.86	5.51	4.78	-1.25
Farming Experience	26.46	15.53	23.32	14.20	24.90	14.94	-2.11^{**}
Farm Size	3.79	2.65	3.70	0.19	3.75	2.68	-0.32
Education	2.17	4.24	1.68	3.80	1.93	4.03	-1.20
Distance to market	8.11	7.08	8.47	7.32	8.30	7.19	0.51
Extension Services	0.29	0.46	0.15	0.36	0.22	0.42	-3.39^{***}
Size of land owned	3.56	2.46	3.35	2.61	3.45	2.53	-0.86
Hired Labour	125.71	240.71	79.16	142.01	102.43	198.74	-2.35^{**}
Risk attitude	5.93	2.69	5.53	2.66	5.73	2.68	-1.49

Note: *, **, *** show significance at 10%, 5%, and 1% levels, respectively
Source: Author

Table 4.2 shows the descriptive statistics of categorical variables used in the econometric models for the entire sample and the two sub-samples of non-adopters and adopters indicating the frequencies and percentages.

There is no significant difference in gender of farmers between the two groups. On average, 85.5% farmers are male. There is no statistical difference in the level of education of the farmers. Adopters are less engaged in off farm activities (30%) compared to non-adopters (40.5%). There is a significant difference in farmer based organization (FBO) membership at 1%. The percentage of FBO membership is higher for adopters. 45% of adopters are members of a farmer based organization compared to 22% for non-adopters. On average, 64% of respondents own livestock. There is no statistical difference in access to credit between both groups. On average, only 19% of farmers had access to credit. The same for the discount factor, about 76% of farmers have preference for present. There is no statistical difference in irrigation practice; only, 2% of respondents practiced irrigation.

Table 4.2: Descriptive statistics for categorical variables

Variable	Category	Adopters		Non-Adopters		Total		X^2value
		No.	%	No.	%	No.	%	
Gender	male	166	83	176	88	342	85.5	2.02
	female	34	17	24	12	58	14.5	
Off-farm Act.	yes	60	30	81	40.5	141	35.25	4.83***
	no	140	70	119	59.5	259	64.75	
FBO	yes	90	45	44	22	134	33.5	23.75***
	no	110	55	156	78	266	66.5	
Livestock	yes	130	65	126	63	256	64	0.17
	no	70	35	74	37	144	36	
Credit Access	yes	38	19	38	19	74	19	0.00
	no	162	81	162	81	324	81	
Disc. Factor	yes	148	74	159	79.5	307	76.75	1.69
	no	52	26	41	20.5	93	23.25	
District	Mion	80	40	80	40	160	40	0.00
	WM[7]	120	60	120	60	240	60	
Irrigation	yes	4	2	4	2	8	2	0.00
	no	196	98	196	98	192	98	

Note: *, **, *** show significance at 10%, 5%, and 1% levels, respectively

Source: Author

4.2.2. Estimation results of the double hurdle model

A test for the existence of multicollinearity has been run using the Variance Inflation Factor method prior to the estimation of results of the double hurdle model. All coefficients are lower than 10, meaning that there is no serious multicollinearity problem in the adoption model. The magnitude of Variance Inflation Factor (VIF[8]) for each explanatory variable is shown in Appendix C.

Columns 2 and 4 of Table 4.3 present the marginal effects for the participation equation (farmers' decision to grow Jatropha on their land) and the intensity decision (Jatropha

[7] West Mamprusi District

[8] The VIF computes $\frac{1}{1-R^2}$ for each explanatory variable in a simple regression. R^2 is the coefficient of determination. According to Greene (2008), the Variance Inflation Factor for a variable provides the increase in the variance of the coefficient that can be due to non-orthogonality with other variables.

land allocation decision) respectively. Variables such as District, age, number of adult members in the household, extension services, off-farm activities, hired labour, FBO and risk attitude are significant in explaining Jatropha adoption. The variables gender, District, access to credit and distance to market have significant effects on Jatropha land allocation.

The variable "age" has a positive and significant influence on the probability of Jatropha adoption. For each year increase in age of a farmer, the adoption of Jatropha increases by 0.5 per cent. This result is surprising. The expected sign was negative. It was hypothesized that young farmers have more years ahead to receive the returns from their investment in Jatropha compared to older farmers. This result could reflect a situation where younger farmers face limited financial resources that make them risk averse. However, older farmers might have both a stable economic situation and a positive attitude towards Jatropha. This could result in high adoption rate.

The variable "District" has a negative and significant effect on both Jatropha adoption (5 per cent level) and Jatropha land allocation (1 per cent level). Being located in West Mamprusi District significantly reduces the adoption of Jatropha by 13.8 per cent. This variable has the expected sign. This is likely due to greater access to a potential market in Mion District. The NGO New Energy is buying the seeds from the farmers in Mion District.

The number of times of access to extension services positively influences the probability of adopting Jatropha. On average, the probability of Jatropha adoption increases by 6.9 per cent each time the farmer has access to extension services. This variable has the expected. Goswami & Choudhury (2015) also found that access to extension services has a positive effect on Jatropha adoption in India. Access to extension services could then play an important role in Jatropha adoption in Northern Ghana for instance in educating farmers in land use decisions concerning Jatropha.

The variable “number of adults” has a positive and significant effect on the probability of Jatropha adoption (at 10 per cent level). These results are in line with Negash (2015). Cheteni et al. (2014) confirmed the positive effect of household size on the probability of biofuel crops adoption in South Africa. Since Jatropha is known as a labour intensive crop (Achten et al., 2008), the more the number of adults in the household, the more available labour is for Jatropha cultivation.

Engagement in off-farm activities has a significant (at 5 per cent level) but negative influence on the probability of Jatropha adoption. It decreases the probability of Jatropha adoption by 10.3 percent. This is in line with Goswami & Choudhury (2015) in the context of decision to adopt and continue with Jatropha in North East India; Negash (2015) in the context of decision to allocate land for castor bean cultivation in Ethiopia and Jensen et al. (2007) in the context of farmer willingness to grow switchgrass for energy production in Tennessee. However, this variable does not have the expected positive sign. It was expected that engagement in off-farm activities provides farmers with additional income enabling them to invest for the lengthy gestational period of Jatropha. The current result might be due to the fact that farmers engaged in off-farm activities have less time and resources to engage in Jatropha cultivation.

Distance from home to the nearest agricultural market has a significant (at 5 per cent level) negative effect on Jatropha land allocation. A kilometer increase in the distance from the nearest agricultural market decreases Jatropha land allocation by approximatively 0.01 hectares. The variable has the expected sign. This result suggests that farmers living far away from agricultural market tend to allocate smaller proportions of their land to Jatropha. Farmers might prefer investing more land in food crops that can be sold in an agricultural market than Jatropha cultivation. The variable is not significant in explaining the probability of Jatropha adoption (also observed by Goswami & Choudhury (2015) and Cheteni et al. (2014)).

The number of man-days hired positively influences probability of Jatropha adoption (at 1 per cent level) even though the effect is not visible at the margin (0.0). Since Jatropha is known as labour intensive, the ability of farmers to hire labour could increase its adoption. Membership of a FBO significantly (at 1 per cent level) increases the probability of Jatropha adoption by 20 per cent. Indeed, FBO might assist farmers to manage the crop, find market and get access to loans.

Gender has no significant effect on probability of Jatropha adoption. Being a female farmer (head of the household) significantly decreases Jatropha land allocation by 0.121 hectares compared to being a male. Being a female headed household does not necessarily imply that the farming decisions are made by a female farmer. Male headed households are more likely to be risk takers compared to female and therefore are more likely to allocate larger land allocation to Jatropha.

The results of risk attitude variable shows that the greater the degree of risk loving, the higher the probability of adopting Jatropha. The more risk loving the farmer is, leads to an increase in the probability of Jatropha adoption by 2.9 percent compared to being a risk avoider. No markets for bioenergy crops currently exist for all Jatropha farmers, making it an uncertain and risky decision for farmers to grow Jatropha. This is in line with Goswami & Choudhury (2015), Lynes et al. (2012) in the context of farmers' willingness to grow an annual bioenergy crop in Kansas, USA. The variable capturing time preferences (discount factor) has no significant effect on both Jatropha land allocation and adoption as found by Bocqueho et al. (2015) in the context of decision to adopt miscanthus and its extent. This result was not expected since Jatropha establishment costs are not subsidized in anyway.

The variable "farm size" has no significant effect on both the probability of Jatropha adoption and the intensity of adoption. It was expected that farm size has a positive effect on Jatropha participation decision based on past studies (Bocquého et al., 2015; Breen et al., 2009; Clancy et al., 2011; Negash, 2015; Rämö et al., 2009; Roos et al., 2000). However, Lynes et al. (2012) confirmed that there is no significant relationship.

Farming experience has no significant influence on both Jatropha adoption and land allocation. This is in line with Goswami & Choudhury (2015) and Lynes et al. (2012).

Livestock ownership, access to credit and Size of land owned have no significant effect on both the probability of Jatropha adoption and land allocation. This is in line with Caldas et al. (2014) and Lynes et al. (2012) concerning livestock and with Cheteni et al. (2014), Bocquého et al. (2015), Clancy et al. (2011), Paulrud & Laitila (2010), Breen et al. (2009) concerning land ownership. However, it was expected that Size of land owned has a positive and significant relationship with both adoption and its extent. In fact, perennial bioenergy crops such as Jatropha are known for their long establishment periods. The more land a farmer owns, the more he could adopt and allocate land to such a perennial crop.

Table 4.3: Marginal effects of the double hurdle model

Variables	Probit		Truncated Regression	
	Marginal Effect	Standard Error	Marginal Effect	Standard error
Gender	0.098	0.070	-0.121**	0.053
	-0.119**	0.061	-0.138***	0.052
Education	0.009	0.006	-0.001	0.004
Age	0.005**	0.002	0.002	0.002
Number of adults	0.009*	0.005	0.002	0.004
Farming Experience	-0.000	0.002	-0.003	0.002
Farm Size	-0.039	0.026	-0.023	0.022
Extension Services	0.069***	0.024	0.016	0.015
Off-farm Activities	-0.103**	0.049	-0.006	0.040
Livestock	0.033	0.050	-0.063	0.003
Credit Access	0.014	0.064	0.093*	0.049
Distance to market	-0.000	0.004	-0.006**	0.003
Hired Labour	0.000***	0.000	-0.000	0.000
Size of land owned	0.022	0.028	0.036	0.024
FBO	0.201***	0.051	0.019	0.039
Risk Attitude	0.029***	0.010	0.003	0.008
Discount factor	-0.061	0.062	0.015	0.049
Irrigation	-0.015	0.159	0.141	0.128
Observations	400		200	
Pseudo R^2	0.1269		-	
p-value	0.000		0.000	
Log-likelihood	-242.08		--1.887	
Wald χ^2 (LR χ^2)	70.35***(18 df)		32.21**(18 df)	

*** p<0.01, ** p<0.05, * p<0.1

Source: Author

4.3. Factors Explaining Farmers' Decisions to Adopt Jatropha either on Fertile or Marginal Lands in Northern Ghana

4.3.1. Descriptive statistics

Data was collected from 400 farmers (200 adopters and 200 non-adopters). In this study an adopter is a farmer who is currently growing Jatropha in his/her field. Table 4.4 shows the descriptive statistics for the adoption of Jatropha on fertile land and marginal land. There is statistical difference at 5% in Jatropha adoption on fertile and marginal lands. 84% of adopters grow Jatropha on fertile lands while 16% grow on marginal lands.

In addition among Jatropha adopters, 11.5% of farmers have uncultivated plot. The reasons are either that the land was fallow, marginal or farmers lack money to invest.

Table 4.4: Descriptive statistics for adoption on fertile land and marginal land

Variable	Category	Adopters		Total		X^2value
		No.	%	No.	%	
Fertile Land	yes	168	84	168	42	289.65***
	no	32	16	232	58	
Margin. Land	yes	32	16	32	8	34.78***
	no	168	84	368	92	

Source: Author

4.3.2. Estimation results of the bivariate probit model

Table 4.5 shows the marginal effects of the bivariate Probit model explaining farmers' decision to grow Jatropha on fertile land and marginal land.

It can be seen from Table 4.5 that some explanatory variables are significant only for a particular type of land and not for the other. For instance, "District", "off-farm activities" and "credit access" are significant only on marginal land. "Number of adults", "Education", "Hired labour", "Age", "Extension services", "FBO" and "Risk attitude" are significant for fertile land only.

Farmers located in West Mamprusi District are less likely to grow Jatropha on marginal lands. The effect is significant at 5 per cent level with a coefficient of 5.4 per cent. From the field survey, the reason could be for the sake of labour costs and monitoring. In addition the cost associated with cultivating Jatropha on marginal land is expected to be higher than that on fertile land. On marginal land, access to credit significantly (at 10 per cent level) influences Jatropha adoption. It means that availability of market in the District is the real driver of investments in Jatropha.

Having access to credit increases Jatropha adoption by 4.9 per cent on marginal land. The cost of cultivating Jatropha on marginal land is expected to be higher than that of on fertile land. Access to credit could enable farmers meeting these costs.

Engagement in off-farm activities decreases the probability of adopting Jatropha on marginal by 4.8 per cent. This is in line with Mponela et al. (2011) in the context of Jatropha adoption on unproductive lands in Malawi. This might be due to the fact that farmers engaged in off-farm activities have less time and resources to engage in Jatropha cultivation.

Livestock ownership has no significant effect on Jatropha adoption in both marginal and fertile lands. This result is in line with Bocquého et al. (2015) in the context of farmers' decision to adopt miscanthus on marginal lands. This result is surprising especially for Jatropha adoption on marginal land since marginal land is assumed to be used for fodder and thus compete with Jatropha.

On fertile land, an additional adult member in the household significantly (5 per cent level) increases the probability of adoption by 0.6 per cent. Indeed, growing Jatropha on fertile land could be understood as farmers' commitment to engage in Jatropha farming. The use of adult members as an additional labour for Jatropha cultivation might increase the probability of adoption. The number of years of education increases the probability of adopting Jatropha on fertile land by 1.3 per cent. The variable Age increases the probability of adopting Jatropha on fertile lands by 0.6 per cent. The significance (at 1 per cent level) of the variable "Hired labour" indicates that each additional number of man-days hired increases the probability of adoption on fertile land. The more a farmer has the ability to hire labour the higher the probability of adopting on fertile land compared to marginal land. During focus group discussions some farmers indicated that for the sake of labour cost and monitoring, farmers tend to grow Jatropha on fertile lands that are closer to their food crops.

On fertile land, being a member of a FBO increases the probability of adoption by 23.5 per cent. Farmers might have learnt from their FBOs that growing Jatropha on fertile land provides higher yield, thus more gains compared to marginal land. On fertile land, an increase of the risk attitude coefficient leads to an increase of the probability of adoption by 4.4 per cent. Indeed, Jatropha is known for its ability to grow on marginal land, and therefore minimizes the negative impact on food crops production in the case where it is grown on fertile land. Only risk seeking farmers would grow Jatropha on their fertile land.

The more the number of visits to the extension service the higher the probability of adopting Jatropha on fertile land. The variable extension services increases the probability of adopting Jatropha on fertile land by 5.2 per cent.

Table 4.5: Marginal effects of the bivariate Probit model

Variables	*Fertile_adopt*		*Marginal_adopt*	
	Marginal Effect	Standard Error	Marginal Effect	Standard Error
Gender	0.109	0.078	-0.002	0.031
District	-0.070	0.072	-0.056**	0.025
Education	0.013*	0.007	-0.002	0.003
Age	0.006**	0.003	-0.001	0.001
Number of adults	0.009*	0.005	-0.002	0.003
Farming experience	0.000	0.003	-0.000	0.001
Farm size	-0.018	0.012	-0.003	0.006
Extension services	0.052**	0.025	0.014	0.010
Off-farm activities	-0.081	0.057	-0.048**	0.023
Livestock	-0.001	0.057	0.035	0.022
Credit access	-0.061	0.078	0.049*	0.023
Distance to market	-0.005	0.005	-0.000	0.001
Hired labour	0.001***	0.000	-0.000	0.000
Size of land owned	0.034	0.031	0.002	0.017
FBO	0.235***	0.060	0.008	0.023
Risk attitude	0.044***	0.012	-0.005	0.004
Discount factor	-0.082	0.068	0.002	0.022
Irrigation	-0.091	0.191	0.003	0.072
Observations	400			
Log likelihood	-306.01			

*** p<0.01, ** p<0.05, * p<0.1

Source: Author

4.4. Impact of Jatropha Adoption on Total Crop Incomes of Farmers

4.4.1. Descriptive statistics

Data was collected from 400 farmers (200 adopters and 200 non-adopters). In this study an adopter is a farmer who is currently growing Jatropha in his/her field. Table 4.6 shows the descriptive statistics for total crop incomes per hectare of farmers. There is a significant difference at the level of 1% for the level of total crop incomes per hectare between adopters and non-adopters. On average adopters have GH₵ 641.92 per hectare as total crop incomes while non-adopters have GH₵ 1,243.41 per hectare. Nonetheless, descriptive statistics cannot explain whether the observed difference in crop income per hectare between adopters and non-adopters is due to Jatropha cultivation. The noted differences in crop income per hectare depending on the adoption status of the household might not be the result of Jatropha adoption but rather might be due to other factors, farm and farmers' characteristics for instance. The impact analysis of Jatropha adoption on total crop incomes per hectare is preceded by the determination of the propensity scores for the treatment variable (adoption status of Jatropha).

Table 4.6: Descriptive statistic for total crop incomes per hectare

Total crop incomes (GH₵ /ha)	Mean	SD
Adopters	641.92	528.92
Non-adopters	1243.41	1235.74
Total	942.67	995.90
t-value	6.32***	

Source: Author

4.4.2. Estimation of the propensity scores

A Probit model has been used to predict the probability of adopting Jatropha. The results of the propensity scores are reported in Appendix A.

Table 4.7 provides the distribution of the propensity scores.

For adopters, the estimated propensity scores vary between 0.06356 and 0.98953 with a mean of 0.50168. For non-adopters, it varies between 0.06356 and 0.89317 with a mean of 0.42073. The results suggest that the region of common support is satisfied in the interval [0.06356, 0.89317]. The consequence of this restriction is observations falling outside that range of the region will be discarded from the analysis. As a result, 9 observations have been removed from the analysis. The common support condition is imposed in the regression models by matching in the region of common support only.

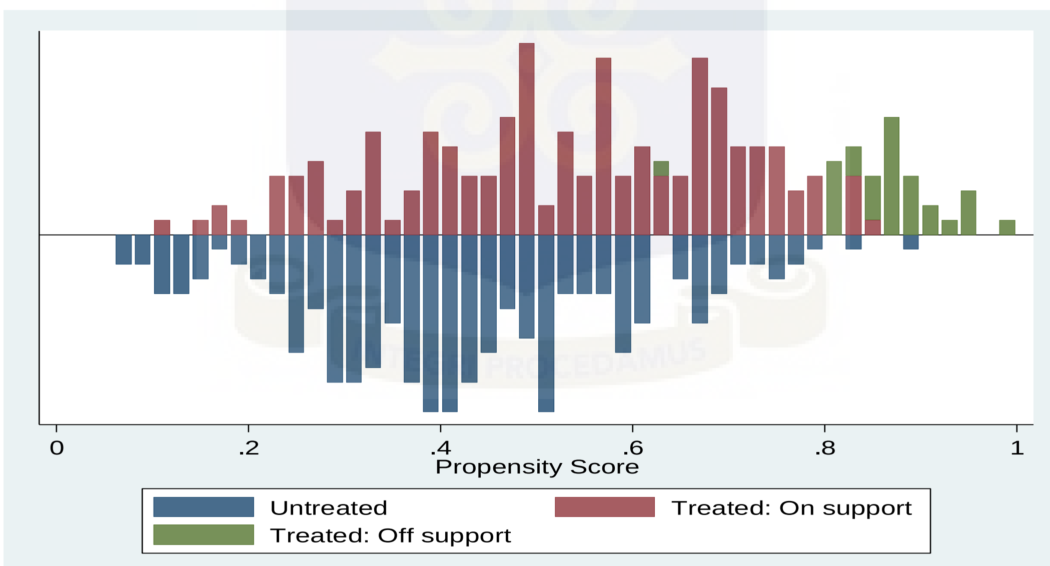
Table 4.7: Estimated propensity scores

Sample	Observations	Mean	SD	Minimum	Maximum
Whole sample	400	0.50168	0.20187	0.06356	0.98953
Adopters	200	0.58263	0.19964	0.11644	0.98953
Non-adopters	200	0.42073	0.16935	0.06356	0.89317

Source: Author

The distribution of the propensity scores and the region of common support before and after matching are represented in Figures 4.1.

Figure 4.1: Propensity score distribution and common support for propensity score estimation



Source: Author

Table 4.8 reports the estimates of the average adoption effects estimated by Nearest Neighbor Matching with replacement. The analysis is based on the restriction of the region of common support.

Table 4.8 shows that adoption of Jatropha significantly reduces crop income per hectare of farmers. The ATT estimate per hectare is negative (GH₵ -385.230). This is probably due to the fact that most farmers grow Jatropha on their fertile lands. Jatropha production is likely to compete for land with food production resulting in smaller areas cultivated and less food grown at the local level. The absence of market for Jatropha especially in the West Mamprusi District makes income generation from Jatropha very difficult. This results in reducing total crop incomes of farmers.

Table 4.8: Average treatment effects (ATT) of Jatropha adoption on crop income

Matching algorithm	Sample	ATT	Number of treated	Number of control
Nearest neighbor Matching with Replacement	400	-385.230*** (-3.05)	170	200

Note: *, **, *** show significance at 10%, 5%, and 1% levels, respectively. Bootstrapped t-values are in parentheses.

Source: Author

4.4.3. Indicators of matching quality before matching and after matching

Table 4.9 provides the indicators of matching quality.

It reveals the results from covariate balancing tests before and after matching. It can be seen that all indicators of matching quality before matching significantly exceed those after matching. After matching, the results show an insignificant likelihood ratio test supporting a rejection of the joint significant of covariates. In addition, after matching the results reveals a lower pseudo-R^2. Indeed, the pseudo R^2 dropped from 0.127 to 0.051 after matching. After matching, there is also a reduction in absolute bias for overall covariates used to estimate the propensity score. Table 4.9 also reveals a mean standardized bias lower than 20% after matching as recommended by Rosenbaum & Rubin (1985). The standardized mean difference for overall covariates used in the propensity score around 15.0% before matching is reduced to about 13.3% after matching. This leads to a substantial reduction of the total bias of 11.33% through matching. All these statistics suggest that the specification of the propensity score is fairly successful in balancing the distribution of covariates between adopters and non-adopters. These results can then be used to assess the impact of Jatropha adoption among groups of farmers having the same observed characteristics.

Table 4.9: Matching quality indicators before and after matching for the whole population

Matching quality indicators	Before matching	After matching
Pseudo R^2	0.127	0.051
LR χ^2	70.35	23.89
$p \succ \chi^2$	0.000	0.159
Mean standardized Bias %	15.0	13.3
Total % |bias| reduction	11.33	

Source: Author

4.5. Farmers' Preferences for Contracts to Produce Jatropha

4.5.1. Descriptive statistics

Table 4.10 shows the descriptive statistics of the variables used in the econometric models.

The data are collected from 400 farmers (200 Jatropha adopters and 200 non-adopters). On average, 14.5 percent of the respondents are female while 85.5 percent are male. 60 percent of the respondents are from West Mamprusi District while 40 percent are from

Mion District. On average the net revenue of the crop most likely to be substituted by Jatropha is GH₵ -1,478.33 per hectare. The variance of the crop most likely to be substituted with Jatropha is 2805. On average 35.75 percent of the respondents are risk averse while 49.75 percent are risk loving.

Table 4.10: Variables description

		Mean	S.D.
Risk perception variables			
Net revenue (scaled by /100) (GH₵)		-14.78	1.51
Variance (σ^2) (scaled by /1000)		2.80	50.38
Risk preference variables			
δ_i^{SA} : Self assessment risk preference measure	Risk averse	0.3575	0.479
	Risk seeking	0.4975	0.500
	Risk neutral (Omitted based category)	0.145	
δ_i^{PSY} : Psychometric risk preference measure	Risk averse	0.26	0.44
	Risk seeking	0.70	0.46
	Risk neutral (OBC)	0.04	
Socio-economic variables			
Gender (Female=1)		0.145	0.35
Adopter (Yes=1)		0.5	0.5
District (West Mamprusi=1, Mion=0)		0.8	0.4

N respondents=400

Source: Author

Table 4.11 represents the crops grown by the farmers and those most likely to be substituted based on subjective risk elicitation. Maize, groundnut, rice and beans are the crops most produced by the farmers. Farmers were asked to state a single crop from their current crop mix for which they were most likely to substitute with Jatropha. That crop then served as the "status-quo" alternative throughout the choice experiment.

Table 4.11: Food crops produced and crops most likely to be substituted with Jatropha

Crops	Current Crop Produced (Frequency of responses)	Crop most likely to be substituted with Jatropha (Frequency of responses)
Maize	352	163
Groundnut	152	57
Rice	134	25
Beans	107	28
Millet	77	51
Yams	77	23
Okro	33	12
Cowpeas	21	14
Sorghum	20	8
Cassava	19	15
Soyabeans	17	2
Tomato	6	2
Cotton	1	-
Total		**400**

Source: Author

In order to see whether farmers' subjective assessment of the crop most likely to be substituted with Jatropha agrees with the objective assessment, the different crop budgets for some crops such as maize, jatropha, sorghum, soyabean, groundnut and rice are established (Appendix D). Objective risk differs from subjective risk in the sense that it is more precisely observable and therefore measurable. The crop budget for maize is GH₵ 1,704.3 per hectare; the crop budget for sorghum is GH₵ 2,005.64 per hectare, the crop budget for rice is GH₵ 1,642.55 per hectare, the crop budget for soyabean is GH₵ 1,395 per hectare, the crop budget for groundnut is GH₵ 1,160.9 per hectare and the crop budget for Jatropha is GH₵ 1,309.1 per hectare. When analyzing the crop budgets for these different crops, it can be observed that the cost of producing Jatropha is higher than the cost of producing groundnut only. The cost of producing Jatropha is lower than that of maize, rice, sorghum and soyabean. Taking this into consideration, it would be rational for farmers to substitute crops such as rice, maize, sorghum and soyabean.

Table 4.12 shows the frequencies at which producers have chosen a contract alternative to produce Jatropha and to maintain current crop production (status-quo, No contract). Contract A, B, …, P are the different combinations of attributes and their levels generated using the orthogonal design facility in SPSS. The 400 respondents were presented with the description of the attributes used in the choice experiment and they were asked to state their preferred contract among 3 contracts alternatives in eight choice sets. Overall, a total of 3200 choices (400*8) were elicitated from 400 respondents. Each choice set is made of 2 alternatives or contract profiles and one opt-out option (Possibility of maintaining current crop mix). This makes in total 3 contract profiles. For each choice set a single farmer faces 3 contract profiles to choose from. In total farmers have chosen one of the contract alternatives 2914 times though the opt-out option has been chosen only 286 times Table 4.12 reveals that in more than 90% of cases one of the contract alternatives was chosen over the status quo (No contract).

Table 4.12: Farmers' choice of Jatropha contract vs. current crop

Contract	Frequency	Percentage
Contract alternatives (A, B,...,P)	2914	91.0625%
No contract	286	8.9375%
Total	**3200**	**100%**

Source: Author

Table 4.13 shows the current state of different contract attributes included in the study (except the price) for the 200 Jatropha farmers. Table 4.13 shows that 19% of interviewed farmers currently growing Jatropha had a written contract. 61% of these farmers received seeds and technical training; only 6.5% received fertilizers and pesticides from the buyer. 98% of them did not have a renegotiation option.

Table 4.13: Stated contract attributes by Jatropha farmers

Contract attributes	Yes		No	
	Frequency	%	Frequency	%
Written Contract	38	19%	162	81%
Seed	122	61%	78	39%
Fertilizers and pesticides	13	6.5%	187	93.5%
Technical training	122	61%	78	39%
Renegotiation option	4	2%	196	98%

Source: Author

4.5.2. Farmers' preferences for Jatropha contract attributes assuming homogeneity of preferences

The results of the Discrete Choice Experiment are based on the responses of 400 farmers and 9600 observations. Results from Table 4.14 show that all the attributes are statistically significant except renegotiation option across models. It is found that "written contract", "Seeds, technical training, fertilizers and pesticides", "Seeds, fertilizers and pesticides" and "Seeds and technical training" increase the likelihood of Jatropha contract acceptance from the respondents' preferences. These results are in line with Interis & Cordero-salas (2016) in context of farmers' preferences to enter into production contract with a buyer of their product in Northern Ghana. They found that farmers prefer a written contract with support from the buyer in the form of seed, fertilizers and pesticides.

Although "Renegotiation option" is not significant across models, except in the model with interaction, the results show that the presence of renegotiation option also increases contract acceptance (Cembalo et al., 2014). Finally, all choice question order variables are not statistically significant, meaning that there is no order driven status quo bias. The results are consistent with expectations.

Table 4.14: RPL estimates for Attribute-only model assuming homogeneity of preferences

Variable	Attribute-only	
	Coefficient	**Std. Dev.**
Random parameters in utility functions		
α_0 , η_i (alternative-specific constant)	-0.514 (0.331)	1.789*** (0.234)
$\ln \beta(-price)$	0.926*** (0.095)	-
β, v (Written contract)	1.858*** (0.166)	2.453*** (0.173)
β, v (Seeds, technical training, fertilizers and pesticides)	2.101*** (0.141)	1.299*** (0.154)
β, v (Seeds, fertilizers and pesticides)	1.155*** (0.101)	0.729*** (0.171)
β, v (Seeds and technical training)	1.571*** (0.183)	1.199*** (0.229)
β, v (Renegotiation option)	0.149 (0.144)	0.921*** (0.197)
Non-random parameters in utility functions		
γ_2	0.486 (0.335)	-
γ_3	0.402 (0.336)	-
γ_4	0.323 (0.326)	-
γ_5	0.412 (0.329)	-
γ_6	0.436 (0.321)	-
γ_7	0.157 (0.350)	-
γ_8	0.348 (0.347)	-
Log likelihood, AIC	-2420.333	1.525
N observations=9600	N respondents=400	
***, **,*: significance at 1%, 5%, and 10%	Figures in parenthesis refer to standard errors	

Source: Author

4.5.3. Preference heterogeneity for contract attributes

A significant standard deviation for a random parameter reveals unobserved heterogeneity among the farmers for that specific attribute. The results presented in Table 4.14 show that the standard deviation for all attributes is significant meaning that there is significant preference heterogeneity among attributes preferences. The results indicate that although the mean preferences for written contract as the nature of contract is positive, 91.25% of farmers have positive preference parameters while 8.75% of the farmers put negative weights on that attribute. In the case of written contract the heterogeneity among farmers was very large as the standard deviation is larger than the mean coefficient. The results also indicate that 10.75% of farmers assign a weight less than one while 89.25% assign a weight greater than one for the attribute “Seeds, technical training, fertilizers and pesticides”. The same goes for the attribute “Seeds and technical training” where 38% of respondents assign a weight less than one while 62% assign a weight greater than one. Although the mean preference for the attribute “Seeds and technical training” is positive, 1.5% of respondents assign a negative weight while 98.5% put positive weight to that attribute. The mean preference for “Renegotiation option” is positive. However, 35.25% of farmers put negative weight while 64.75% put positive weight on “renegotiation option” attribute. The significance of the standard deviation for the constant term suggests that there is a difference in scale of the variance across alternatives. In other words, the Independence of Irrelevant Alternatives (IIA) assumption is so violated. This result supports the use of the Random Parameter Logit (RPL) model in order to relax this assumption.

4.5.4. Sources of heterogeneity for contract attributes

Socio economic variables have been interacted with Jatropha contract attributes in the Random Parameter Model (RPL) in order to account for preferences heterogeneity. After extensive testing of the various interactions of the four contract attributes with the respondents' socio economic characteristics collected in the survey, the model that includes District, gender and Jatropha adoption status was found to fit the data the best. The inclusion of the interaction terms reveals the source of heterogeneity and an improvement of the attribute-only as shown by the likelihood test and AIC (See Table 4.15 below). The log-likelihood ratio test rejects the null hypothesis that the regression parameters for the attribute-only model and the model with interactions are equal at 1% significance level, implying that improvement in the model fit is achieved with the inclusion of socio, economic characteristics in the attribute-only model. In addition, the model with interaction presents a lower AIC which indicates a better for than the attribute-only model. The additional heterogeneity revealed by the model with interaction is that in West Mamprusi District, farmers tend to choose more the alternative with a "written contract" form and "seeds, technical training, fertilizers and pesticides" as support from the buyer than in Mion. However, they are less likely to choose the alternative with a "renegotiation option" than those in Mion. Farmers who currently grow Jatropha are less likely to prefer "seeds, technical training, fertilizers and pesticides" as support from the buyer than those not growing Jatropha. This might be due to the fact that having experience in Jatropha contract farming they assume that if they get all this support from the buyer, the price per kilogram harvested may be lower.

Female respondents are less likely to accept a contract to produce Jatropha in the case the buyer provides support in terms of "seeds and technical training".

Table 4.15: RPL estimates for the model with interaction between attributes and socioeconomic variables

Variable	Model with interaction	
	Coefficient	Std. Dev.
Random parameters in utility functions		
α_0 , η_i (alternative-specific constant)	-0.515 (0.331)	1.733*** (0.239)
$\ln \beta(-price)$	0.921*** (0.096)	-
β, v (Written contract)	0.660*** (0.216)	2.313*** (0.170)
β, v (Seeds, technical training, fertilizers and pesticides)	1.782*** (0.239)	1.235*** (0.152)
β, v (Seeds, fertilizers and pesticides)	1.174*** (0.106)	0.780*** (0.171)
β, v (Seeds and technical training)	1.698*** (0.194)	1.271*** (0.235)
β, v (Renegotiation option)	0.806*** (.0184)	0.852*** (0.218)
β_1, v (District*Written contract)	2.009*** (0.308)	-
β_2, v (District*renegotiation option)	-1.228*** (0.235)	-
β_3, v (District* Seeds, technical training, fertilizers and pesticides)	1.042*** (0.246)	-
β_4, v (Adopter* Seeds, technical training, fertilizers and pesticides)	-0.446*** (0.217)	-
β_5, v (Gender* Seeds and technical training)	-0.808*** (0400)	-
Non-random parameters in utility functions		
γ_2	0.480 (0.341)	-
γ_3	0.381 (0.342)	-
γ_4	0.326 (0.339)	-
γ_5	0.414 (0.338)	-
γ_6	0.430 (0.329)	-
γ_7	0.103 (0.354)	-
γ_8	0.350 (0.354)	-
Log likelihood, AIC	-2366.539,	1.495
LRstatistic (χ^2) $H_0 : \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$	107.588***(4ddf)	

N=9600 panel=400 observations Figures in parenthesis refer to standard errors ***, **,*: significance at 1%, 5%, and 10%

Source: Author

4.5.5. Status-quo and risk information effects

Table 4.16 provides the results of the RPL when accounting for status-quo and risk. It was expected that an increase of net revenue on a farmer' current crop reduces the likelihood of accepting a contract to produce Jatropha. However, the results show a significant positive coefficient across models. This result is contradictory with Krah et al. (2015) who found that though the mean net revenue increases the likelihood of accepting a contract to produce Giant Miscanthus in the US, the coefficient is not significant. This might be due to the fact that perhaps majority of the respondents were more interested in stating their preferences on contract attributes among the ones available rather than just refusing the contract. Indeed, Table 4.12 earlier showed that about 91% of respondents chose to enter into contract to produce Jatropha while only about 9% chose the status quo alternative (No contract).

It was expected that an increase in the variance associated with the current crop (most likely to be substituted with Jatropha) leads to an increase of the likelihood of a risk-averse farmer to accept contract to produce Jatropha. By the same way, the variance associated with the current crop was expected to decrease the likelihood of a risk seeking farmer to accept contract to produce Jatropha. Table 4.16 shows that the coefficients of the different variance associated with risk variables measured through self-assessment risk elicitation have the expected signs and are significant. However, in the model using psychometric risk elicitation, none of the coefficients on the variance associated with risk variables is significant, although having the expected sign. In addition, based on the likelihood ratio tests, there is a significant model improvement across models when risk variables are incorporated in the status quo alternative. Depending of the risk preferences elicitation methods used, the results are different.

Table 4.16: RPL estimates for δ_i^{SA} Model and δ_i^{PSY} Model

	δ_i^{SA} Model		δ_i^{PSY} Model	
Variables	**Coefficient**	**Std. Dev.**	**Coefficient**	**Std. Dev.**
Random parameters in utility functions				
α_0 , η_i	-0.684** (0.344)	1.773*** (0.226)	-1.030*** (0.385)	1.753*** (0.226)
$\ln \beta(-price)$	0.926*** (0.096)	-	0.926*** (0.096)	-
β, v (Written contract)	1.856*** (0.167)	2.461*** (0.172)	1.847*** (0.168)	2.471*** (0.172)
β, v (Seeds, technical training, fertilizers and pesticides)	2.107*** (0.144)	1.310*** (0.154)	2.105*** (0.143)	1.303*** (0.151)
β, v (Seeds, fertilizers and pesticides)	1.158*** (0.102)	0.731*** (0.171)	1.157*** (0.102)	0.722*** (0.172)
β, v (Seeds and technical training)	1.576*** (0.184)	1.218*** (0.223)	1.570*** (0.184)	1.229*** (0.231)
β, v (Renegotiation option)	0.151 (0.146)	0.947*** (0.198)	0.152 (0.144)	0.927*** (0.198)
Non-random parameters in utility functions				
α_μ	0.151** (0.061)	-	0.141** (0.058)	-
α_{RA}	0.136* (0.082)	-	0.112 (0.096)	-
α_{RS}	-0.131** (0.065)	-	-0.099 (0.068)	-
γ_2	0.486 (0.340)	-	0.490 (0.339)	-
γ_3	0.406 (0.340)	-	0.405 (0.338)	-
γ_4	0.334 (0.329)	-	0.328 (0.328)	-
γ_5	0.420 (0.333)	-	0.419 (0.334)	-
γ_6	0.448 (0.325)	-	0.439 (0.324)	-
γ_7	0.154 (0.354)	-	0.160 (0.355)	-
γ_8	0.348 (0.349)	-	0.348 (0.349)	-
Log likelihood, AIC	-2414.966	1.524	-2412.911	1.523
LR statistic (χ^2)	10.734** (4 ddf)		14.844***(4ddf)	

$H_0 : \alpha_\mu = \alpha_{RA} = \alpha_{RS} = 0$

N observations =9600 N respondents=400

***, **,*: significance at 1%, 5%, and 10% Figures in parenthesis refer to standard errors

Source: Author

4.5.6. Welfare estimates

The study follows Bliemer & Rose (2013) in order to calculate the mean and 95% confidence intervals on welfare estimates for individual attribute increment values. The study uses the Delta method with 25,000 random draws. Table 4.17 shows the mean willingness to accept and its associated 95% confidence intervals for each contract attribute. These values are relative to the status quo alternative of not choosing any of the proposed contracts.

The results of Table 4.17 show little or no difference across models except for the model with the interaction. The welfares estimates for the individual contract attributes show the willingness to accept (WTA) a price per kilogram of Jatropha harvested for changes in attributes of a contract.

Taking the Attribute-only model results as representative, regarding the nature of contract, farmers require an additional price of GH₵ 2.00 per kilogram if the contract is in written form. Regarding the attribute support from the buyer, farmers require the highest additional compensation of GH₵ 2.27 per kilogram of Jatropha in addition to receiving support from the buyer in terms of “Seeds, technical training, fertilizers and pesticides” compared to GH₵ 1.25 for “Seeds, fertilizers and pesticides” and GH₵ 1.67 for “Seeds and technical trainings”. In order to have a renegotiation option on the contract terms, farmers require an additional compensation of only GH₵ 0.16 GH₵ per kilogram of Jatropha.

Table 4.17: Mean Willingness to Accept for contract attribute and 95% confidence intervals

Attribute	Attribute-only Model	Model with interaction	δ_i^{SA} Model	δ_i^{PSY} Model
Written contract	2.00 (-3.25, 7.26)	0.71 (-4.26, 5.69)	2.00 (-3.27, 7.27)	1.99 (-3.30, 7.29)
Seeds, technical training, fertilizers and pesticides	2.27 (-0.54, 5.07)	1.93 (-0.78, 4.64)	2.27 (-0.56, 5.10)	2.27 (-0.54, 5.09)
Seeds, fertilizers and pesticides	1.25 (-0.36, 2.86)	1.27 (-0.45, 3.00)	1.25 (-0.37, 2.86)	1.25 (-0.35, 2.85)
Seeds and technical training	1.69 (-0.93, 4.32)	1.84 (-0.95, 4.64)	1.70 (-0.96, 4.36)	1.69 (-0.99, 4.38)
Renegotiation option	0 .16 (-1.86, 2.18)	0.87 (-1.04, 2.79)	0.16 (-1.91, 2.23)	0.16 (-1.87, 2.20)

Source: Author

Note: In parentheses are 95% confidence intervals

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Introduction

This chapter provides the summary of findings, the conclusions and policy recommendations of the study.

5.2. Summary of Findings

This study attempted to assess Jatropha adoption on crop incomes of farmers and their preferences for production contracts in Northern Ghana. The first objective was to identify the factors explaining farmers' adoption and land allocation to Jatropha in Northern Ghana. The second objective was to identify the factors explaining farmers' decisions to adopt Jatropha either on fertile or marginal lands in Northern Ghana. The third objective of the study measured the impact of Jatropha cultivation on farmers' crop incomes in Northern Ghana. The fourth objective was to identify farmers' preferences for contracts attributes in Jatropha cultivation in Northern Ghana.

Different methods have been employed to attain these objectives. In order to analyze factors influencing Jatropha adoption decision and its extent, a double hurdle model has been used. In addition, a bivariate Probit model has been used to analyze Jatropha adoption decision on fertile versus marginal lands. The Propensity Score Matching (PSM) method has been used to analyze the impact that Jatropha adoption could have on the level of total crop incomes of farmers. Through a Discrete Choice Experiment, farmers' preferences for contract to produce Jatropha have been performed using a Random Parameter Logit model.

The results show that being located in West Mamprusi District significantly reduces the adoption of Jatropha by 13.8%. On average, the probability of adopting Jatropha increases by 6.9% each time the farmer has access to extension services. The number of adults in a household has a positive and significant effect on the probability of Jatropha adoption. Engagement in off-farm activities decreases the probability of Jatropha adoption by 10.3%. A kilometer increase in distance from the nearest agricultural market decreases Jatropha land allocation marginally (0.006 hectares). Membership of a FBO significantly increases the probability of Jatropha adoption by 20.1%. Being a female farmer significantly decreases Jatropha land allocation by 0.121 hectares compared to being a male. The more a farmer is risk loving leads to an increase in the probability of Jatropha adoption by 2.9%.

Being located in West Mamprusi District decreases the probability of producing Jatropha on marginal lands by 5.4% compared to being located in Mion District. Having access to credit increases marginal land being used for Jatropha adoption by 4.9 % compared to those who do not have access to credit. Engagement in off-farm activities decreases the probability of adopting Jatropha on marginal land by 4.8 %.

An additional adult member in a household with fertile land significantly (5 per cent level) increases the probability of adoption by 0.6%. Each additional number of man-days of hired labour increases the probability of adopting Jatropha on fertile land. Being a member of a FBO increases the probability of Jatropha adoption by 23.5% on fertile land.

An increase of the risk attitude coefficient increases the probability of fertile land being used for Jatropha adoption by 4.4 %. An additional year added to the age of a farmer increases the probability of adopting fertile lands to Jatropha by 0.6 per cent.

The results showed that Jatropha adoption reduces the total crop incomes of farmers. The Average Treatment Effect on the Treated estimate was GH₵ -385.230 per hectare.

The results on contract showed that higher Jatropha prices, presence of written contract, support from the buyer made through services (such as “Seeds, technical training, fertilizers and pesticides only” or “Seeds, fertilizers and pesticides only” or “Seeds and technical training only”), significantly increase the probability of a producer accepting a Jatropha production contract. Although the mean preferences for written contract as the nature of contract is positive, 91.25% of farmers have positive preference parameters while 18.75% of the farmers put negative weights on written contract attribute. About 11% of farmers assigned a weight less than one while 89% assigned a weight greater than one for the attribute “Seeds, technical training, fertilizers and pesticides”. The same goes for the attribute “Seeds and technical training”; about 38% of respondents assigned a weight less than one while 62% assigned a weight greater than one.

The mean preference for the attribute “Seeds and technical training” was positive; 1.5% of respondents assigned a negative weight while 98.5% put positive weight to that attribute. The mean preference for “Renegotiation option” was positive; 35.25% of farmers put negative weight while 64.75% put positive weight on “renegotiation option” attribute. In West Mamprusi District, farmers prefer more a Jatropha contract having the following attributes: written form and support from the buyer in the form of “seeds, technical training, fertilizers and pesticides" than in Mion District. In West Mamprusi District, farmers are less likely to choose a Jatropha contract having a renegotiation option as attribute. Jatropha adopters are less likely to prefer "seeds, technical training, fertilizers and pesticides" as support from the buyer. Female farmers are less likely to prefer a Jatropha contract if the buyer provides support in terms of "seeds and technical training". The results also show that an increase of net revenue from a farmers' current crop increases the likelihood of accepting a contract to produce Jatropha. An increase in the variance associated with the current crop most likely to be substituted with Jatropha leads to an increase of the likelihood of a risk-averse farmer to accept contract to produce Jatropha. The variance associated with the current crop most likely to be substituted with Jatropha decreases the likelihood of a risk loving farmer to accept contract to produce Jatropha. The presence of written contract adds GH₵ 2 per kilogram, on average, to the value of a Jatropha contract, whereas Seeds, technical training, fertilizers and pesticides adds GH₵ 2.27 per kilogram. The presence of seeds, fertilizers and pesticides adds GH₵ 1.25 per kilogram, whereas the presence of both seeds and technical training adds GH₵ 1.69. The presence of a renegotiation option increases the contract value by only GH₵ 1.69 per kilogram.

5.3. Conclusions

Farm and farmer characteristics, institutional factors and risk preferences have a significant role in explaining farmers' adoption decision on a perennial bioenergy crop such as Jatropha in Northern Ghana. Variables such as District, age, number of adult members in the household, extension services, off-farm activities, hired labour, FBO and risk attitude are significant in explaining Jatropha adoption. The variables gender, District, access to credit and distance to market have significant effects on Jatropha land allocation. The more adult member in the household the more likely farmers will allocate higher amount of land to Jatropha cultivation. The availability of institutional facilities such as access to credit and extension services has a great influence on Jatropha adoption decisions on marginal lands. Farmers can be educated in land use decisions through access to extension services. In addition, access to credit is very important for farmers especially during the first three years of production. Indeed, Jatropha is characterized by a substantial establishment cost. Access to credit would help deal with the initial investment due to the production of a perennial such as Jatropha.

Adoption of Jatropha has a negative impact on total crop incomes per hectare of farmers since the adoption reduces it. Jatropha cultivation might constitute a threat to farmers through a reduction of their total crop incomes because part of the land that could have been used to produce food crops (fertile land) has been diverted to Jatropha cultivation. Farmers prefer Jatropha contract having the following attributes: presence of written contract, support from the buyer made up of either “Seeds, technical training, fertilizers and pesticides only” or “Seeds, fertilizers and pesticides only” or “Seeds and technical training only”. Heterogeneity of farmers’ preferences for Jatropha contract is driven by differences in gender, District and Jatropha adoption status. The presence of each contract attribute stated in the experiment requires an additional price of Jatropha per kilogram harvested in order to include the attribute in question in the contract terms. The thesis emphasizes on the importance of land type when studying adoption of perennial crop such as Jatropha and confirms that marginal land is more suitable for its cultivation.

5.4. Policy Recommendations

1. The promotion of Jatropha cultivation should to be properly regulated to avoid the massive conversion of fertile land used for crop production for Jatropha cultivation. There is a need to develop appropriate strategies and a regulatory framework to harness the potential economic opportunities from Jatropha cultivation, while protecting rural people from converting part of their fertile lands to Jatropha cultivation at the expense of food crops.
2. The promotion of Jatropha cultivation should target the youth and women because they seem to be marginalized from Jatropha cultivation. Few examples of pro-women Jatropha development are the promotion of Jatropha by-products such as traditional soap and fertilizers.
3. Extension and education programmes and access to credit mechanisms should be developed to promote adoption of perennial bioenergy crops. Extension services should work hand-in-hand with Jatropha adopters and let them be part in the awareness creation and promotion of the bioenergy industry.
4. The development of farmer-based organizations is recommended in order to support Jatropha farmers through trainings and finance and thus increasing their negotiating power. Jatropha prices have been poor throughout Africa and farmers have no or little negotiating power for determining sales packages with large private concerns unless they organize themselves as cooperatives
5. For the success of Jatropha based contract, their attributes should address farmers' concerns. Thus, understanding farmers' preferences for Jatropha contract design is an input to this end. The study recommends Jatropha contract design based on

written contract where the contents of the contract between farmers and the investors (buyers) are clearly stated. A contract containing support from the buyer in the form of seed, technical training fertilizers and pesticides should be encouraged.

5.5. Suggestions for Future Research

Future research is encouraged to define the term adoption in the context of time such as early adopters, late adopters, etc. when dealing with bioenergy crops such as Jatropha. Additional evidence might help policy makers generalize the willingness to accept values for each contract attribute in other study locations. The discrete choice experiment is site specific, so one cannot definitively know how to extrapolate results to other locations. Preferences for contract attributes are likely to vary with location; more replications are needed. Preferences for contract attribute such as quality, contract length and penalties for non-compliance should be investigated.

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Appendix A: Maximum Likelihood Estimation of the Double-Hurdle versus Tobit Model

Variables	Probit		Truncated Regression		Tobit	
	Coeff	Standard error	coeff	Standard error	coeff	Standard error
Gender	0.286	0.205	-0.121**	0.053	0.021	0.085
District	-0.345*	0.181	-0.138***	0.053	-0.229***	0.078
Education	0.028	0.018	-0.001	0.004	0.011	0.007
Age	0.014	0.007	0.002	0.002	0.006**	0.003
Number of adults	0.026	0.016	0.002	0.004	0.012**	0.006
Farming Experience	-0.001	0.007	-0.003	0.002	-0.002	0.003
Farm Size	-0.112	0.076	-0.023	0.022	-0.053	0.033
Extension Services	0.200***	0.072	0.016	0.015	0.075***	0.026
Off-farm Activities	-0.299**	0.146	-0.006	0.040	-0.120*	0.062
Livestock	0.097	0.146	-0.063	0.039	-0.010	0.061
Credit Access	0.042	0.187	0.093*	0.049	0.082	0.078
Distance to market	-0.001	0.011	-0.006**	0.003	-0.004	0.005
Hired Labour	0.002***	0.000	-0.000	0.000	0.000***	0.000
Size of land owned	0.063	0.081	0.036	0.023	0.038	0.035
FBO	0.583***	0.155	0.019	0.039	0.240***	0.063
Risk Attitude	0.086***	0.029	0.003	0.008	0.036***	0.012
Discount Factor	-0.178	0.179	0.015	0. 049	-0.058	0.075
Irrigation	-0.043	0.461	0.141	0.128	0.250	0.489
Constant	-1.176	0.335	0.559	0.084	-0.335	0.137
Observations	400		200		400	
Pseudo R^2	0.1269		-		0.1063	
p-value	0.000		0.020		0.000	
Log likelihood	-242.08		-1.73		-273.91	
Wald χ^2 (LR χ^2)	70.35*** (20 df)		32.21** (18 df)		65.13*** (18 df)	

χ^2 Test Double Hurdle versus Tobit: $\Gamma = 60.2 \succ \chi^2_{18} = 9.39$

*** p<0.01, ** p<0.05, * p<0.1

Source: Author

Appendix B: Proof of Equation 3.22

$$\frac{(R-\mu)^2}{2\sigma^2}+\delta R=\frac{(R-\mu)^2+2R\delta\sigma^2}{2\sigma^2} \tag{B.1}$$

From equation (B.1) the expression $(R-\mu)^2+2R\delta\sigma^2$ is similar to the two first terms of $(a+b)^2=a^2+2ab+b^2$, where $a=(R+\mu)$ and $b=\delta\sigma^2$, but just that in the second term $2R\delta\sigma^2$, $-2\mu\delta\sigma^2$ is missing. So we add it and subtract it in the following expression as follow.

$$\Rightarrow\frac{(R-\mu)^2}{2\sigma^2}+\delta R=\frac{(R-\mu)^2+2R\delta\sigma^2}{2\sigma^2}=\frac{(R-\mu)^2+2R\delta\sigma^2-2\mu\delta\sigma^2+2\mu\delta\sigma^2}{2\sigma^2} \tag{B.2}$$

$$\Rightarrow\frac{(R-\mu)^2+2R\delta\sigma^2-2\mu\delta\sigma^2+2\mu\delta\sigma^2}{2\sigma^2}=\frac{(R-\mu)^2+2(R-\mu)\delta\sigma^2+2\mu\delta\sigma^2}{2\sigma^2} \tag{B.3}$$

We also add the third term of the $(a+b)^2=a^2+2ab+b^2$, which is $b^2=(\delta\sigma^2)^2$ and subtract it. Therefore from equation (B.3) we have:

$$\begin{aligned}\Rightarrow\frac{(R-\mu)^2+2(R-\mu)\delta\sigma^2+2\mu\delta\sigma^2}{2\sigma^2}&=\frac{(R-\mu)^2+2(R-\mu)\delta\sigma^2+(\delta\sigma^2)^2-(\delta\sigma^2)^2+2\mu\delta\sigma^2}{2\sigma^2}\\&=\frac{((R-\mu)+\delta\sigma^2)^2-(\delta\sigma^2)^2+2\mu\delta\sigma^2}{2\sigma^2}\\&=\frac{((R-\mu)+\delta\sigma^2)^2}{2\sigma^2}+\frac{2\mu\delta\sigma^2}{2\sigma^2}-\frac{\delta^2\sigma^4}{2\sigma^2}\\&=\frac{((R-\mu)+\delta\sigma^2)^2}{2\sigma^2}+\mu\delta-\frac{\delta^2\sigma^2}{2}\\&=\frac{((R-\mu)+\delta\sigma^2)^2}{2\sigma^2}+\delta\left(\mu-\frac{\delta\sigma^2}{2}\right)\end{aligned} \tag{B.4}$$

Therefore $$\frac{(R-\mu)^2}{2\sigma^2}+\delta R=\frac{(R-\mu+\delta\sigma^2)^2}{2\sigma^2}+\delta\left(\mu-\frac{\delta\sigma^2}{2}\right) \tag{B.5}$$

Appendix C: Variance Inflation Factor (VIF) for Explanatory Variables

Variables	**VIF**
Gender	1.005
Age	1.020
Education	1.004
Number of adults	1.004
Farming Experience	1.011
Farm Size	1.000
Extension Services	1.034
Off-farm Activities	1.012
Livestock	1.000
FBO	1.063
District	1.000
Credit Access	1.000
Distance to Market	1.001
Size of land owned	1.002
Hired Labour	1.014
Irrigation	1.000
Risk Attitude	1.006
Discount Factor	1.004

Source: Author

Appendix D: Crop Budgets Per Hectare

MAIZE

NO	ITEM	UNIT COST (GH₵)	QTY	Unit	TOTAL COST (GH₵ /Acre)	TOTAL COST (GH₵ /Ha)
1	Ploughing	80	1	Acre	80	197.6
2	Seed	6	10	kg	60	148.2
3	Planting & feeding	60	1	Acre	60	148.2
4	1st weeding & feeding	72	1	Acre	72	177.84
5	NPK	60	2	bag	120	296.4
6	Fert. Applica & feeding	30	1	Acre	30	74.1
7	Urea	50	1	Bag	50	123.5
8	2nd Weeding and feeding	30	1	Acre	30	74.1
9	Fert. Applica & feeding	30	1	Acre	30	74.1
10	Harvesting & feeding	30	1	Acre	30	74.1
11	Carting	20	1	Acre	20	49.4
12	Threshing & Winnowing	30	1	Acre	30	74.1
13	Jute Sacks	5	12	Bag	60	148.2
14	Bagging and Packing	1.5	12	bag	18	44.46
	Total cost				690	**1704.3**

SORGHUM

NO	ITEM	UNIT COST (GH₵)	QTY	Unit	TOTAL COST (GH₵ /Acre)	TOTAL COST (GH₵ /Ha)
1	Ploughing	80	1	Acre	80	197.6
2	Seed	3	16	kg	48	118.56
3	Planting & feeding	60	1	Acre	60	148.2
4	1st weeding & feeding	72	1	Acre	72	177.84
5	NPK	60	2	Bag	120	296.4
6	Fert. Applica & feeding	30	1	Acre	30	74.1
7	Urea	50	1	Bag	50	123.5
8	2nd Weeding and feeding	30	1	Acre	30	74.1
9	Urea	50	1	Bag	50	123.5
10	Fert. Applica & feeding	30	1	Acre	30	74.1
11	Pest and Disease Control	60	1	Acre	60	148.2
12	Harvesting & feeding	30	1	Acre	30	74.1
13	Carting	20	1	Acre	20	49.4
14	Threshing & Winnowing	60	1	Acre	60	148.2
15	Jute Sacks	5	12	bag	60	148.2
16	Bagging and Packing	1.5	8	bag	12	29.64
	Total				812	**2005.64**

GROUNDNUT

No	ITEM	QTY	UNIT	UNIT COST	COST (GH₵ /Acre)	TOTAL COST (GH₵ /Ha)
1	Seed	12	Kg	10	120	296.4
2	Ploughing	1	Acre	80	100	247
3	Weeding	1	Acre	150	150	370.5
4	Harvesting	1	Acre	100	100	247
	Total cost				470	**1160.9**

RICE

NO	ITEM	QTY	UNIT	FREQ	Unit cost GHC	TOTAL COST (GHC /Acre)	TOTAL COST (GHC /Ha)
1	Ploughing	1	Acre	1	80	80	197.6
2	Harrow	1	Acre	1	30	30	74.1
3	Seed	20	Kg	1	2	40	98.8
4	Sowing	10	Man days	1	5	50	123.5
5	Herbicide	2	Lit.	1	25	50	123.5
6	Herbicide application	2	Man days	2	5	20	49.4
7	Fertilizer	2	NPK 50kg	1	60	120	296.4
8	Fertilizer	1	Urea 50kg	1	50	50	123.5
9	Fertilizer application	5	Man days	2	5	50	123.5
10	Harvest	10	Man days	1	5	50	123.5
11	Threshing	10	Man days	1	5	50	123.5
12	Winowing and bagging	5	Man days	1	25	25	61.75
13	Bags	10	bag	1	5	50	123.5
	Total cost					665	**1642.55**

JATROPHA

NO	ITEM	Quantity (3 year investment)	Unit	UNIT COST (GHC)	UNIT COST (GHC /Acre)	TOTAL COST (GHC /Ha)	
1	Ploughing	1	Acre	80	80	2.47	197.6
2	Harrowing	1	Acre	30	30	2.47	74.1
3	Seed	1	kg	0	0	2.47	0
4	Planting	1	Acre	30	30	2.47	74.1
5	1st Weeding	3	Acre	40	120	2.47	296.4
6	2nd Weeding	3	Acre	50	150	2.47	370.5
7	Harvesting	1	Acre	60	60	2.47	148.2
8	Trashing	1	Acre	30	30	2.47	74.1
9	Drying and bagging	1	Acre	30	30	2.47	74.1
	Total cost				530	2.47	1309.1

SOYABEAN

INPUT/ACTIVITY	**UNIT**	**QUANTITY**	**UNIT COST (₵) /Ha**	**TOTAL**
Ploughing	Ha	1	150	150
Seed	Kg	40	7	280
Planting (labor)	Ha	1	150	150
Pre-emergent weedicide	Liter	2.5	12	30
Post-emergent weedicide	Liter	2	30	60
Inoculant	Grams	250	0.3	75
1st Weeding	Ha	1	150	150
2nd Weeding	Ha	1	150	150
Harvesting (labor)	Ha	1	150	150
Threshing	Ha	1	100	100
Empty Sacks	Pieces	20	5	100
Total				**1,395.00**

Appendix E: Questionnaire for the Survey

This survey is being carried out by Sandra Boade for her PhD research. The main objective is to assess the opportunities available and challenges encountered by smallholder farmers by participating in Jatropha cultivation in Northern Ghana. All the information gathered will be treated with much confidentiality and would be solely for this academic purpose. Your support and contribution would be very much appreciated. For further enquiries, please contact her on boadesandra@gmail.com or Tel: 00233540350089/00233540350484.

SECTION A- INTRODUCTION

1. Identification [| | |] Code

2. Region………………………………………………………………… **3.** District……………………………….................................

4. Town/Village/community ……………………………............................ **5.** Date of Interview ……...…/.........……/ 2015

6. Name of enumerator ……………………………………………………....... **7.** Telephone number ……………………………………

SECTION B- SOCIO-ECONOMIC CHARACTERISTICS OF THE RESPONDENT (Head of the household)

8. Gender: 1. Male [ ] 2. Female [ ]

9. Name of respondent...

10. Age of respondent……………………........years

11. Marital status: 1. Single [ ] 2. Married [ ] 3. Divorced [ ] 4. Separated [ ] 5. Widowed [ ] 6. Other [ ], specify, …………..................

12. Level of Education 1. No schooling [ ] 2. Primary school [ ] 3. JHS [ ] 4. SSS [ ] 5. College [ ] 6. Other [ ], specify,…………..………..…

13. What is the size of your household (including yourself)…............................person(s).

Number of adults (>18 years)		Number of children < 18 years	
Males	Females	Males	Females

14. For how long have you been farming? …………………………………………………years

15. What is your farm size? …………………………………………………………… (Acres)

16. Have you had access to extension services recently (the last cropping seasons)? 1. Yes [ ] 0. No [ ]; **If No, skip to Q19**

17. If yes, How many times did it happen?...

18. Which kind of services did you receive from the extension officer? (***Multiple response***) 1.Advices[ ] 2.Training[ ] 3. agronomic practices[ ] 4. new technologies [ ] 5. Other specify………………………………………………..

19. Do you belong to any Farmer Based Organization (FBO)? 1. Yes [ ] 0. No [ ] **If No, skip to Q21**

20. What benefits do you derive from membership in this FBO? ***(Multiple Response)*** 1. Inputs procurement [ ] 2. Marketing [ ] 3. Agro processing [ ]

4. Production [ ] 5. community services [ ] 6. Internal credit schemes [ ] 7. Welfare services [ ] 8. Mutual labour support [ ] 9. Other [ ], specify………………………

21. Are you the main decision maker for land management in your household? 1. Yes [ ] 0. No [ ]

22. Did you request for credit during the last growing season? 1. Yes [ ] 0. No [ ] **If No, skip to Q26**

23. Did you receive the credit? 1. Yes [ ] 0. No [ ] **If No, skip to Q27**

24. Please indicate the amount received? (cedis) ………………………………………………………………………………

25. If you receive a cash credit can you indicate the source over the 2015 production year? 1. Banks [ ] 2. Money lenders [ ] 3. Relatives [ ] 4. NGO [ ] 5. FBO [ ] 6. other [ ], specify...

26. Please give reasons why you didn't request for credit. (**multiple responses**) 1. High interest rates [ ] 2. Lack of collateral [ ] 2. Laborious application procedures [ ]4. Does not need credit [ ] 5. Does not know the source of credit [ ] 6. Does not know how to apply for it [ ] 7. Lack of identity papers [ ] 8. Repayment schedule not favourable [ ] 9. Other [ ], specify..

27. What is the most important source of income for your household within the last growing season? 1. Food Crop Production [ ] 2. Tree crop production[ ] 3. Business/ Self employment [ ] 4. Farm Wage Labour[ ] . Non-Farm Wage Labour [ ] 5. Mining [ ] 6. Remittances [ ] 7. Livestock [ ] 8. Other (specify)…………………………………………………………..

28. Are you engaged in any off-farm activity? 1. Yes [ ] 0. No [ ]; **If No skip to Q31**

29. In which off-farm activity are you engaged in? (**multiple response**) 1. Pito /Akpeteshi Brewing [ ] 2. Mason, construction work, etc [ ] 3. Palm Oil Processing [ ] 4. Pottery [ ] 5. Sheabutter/groundnut oil extraction [ ] 6. Mining (quarrying, gold winning, etc) [ ] 7. Charcoal/firewood selling [ ] 8. Butcher [ ]

9. Artisan (blacksmith, carpentry, tailoring) [ ] 10. Salaried employee [ ] 11. Basket weaving [ ] 12. General trade in agricultural goods [ ] 13. General trade in non-agricultural goods [ ] 14. Gari Processing [ ] 15. Smock weaving [ ] 16. Farm Hand [ ] 17. Traditional healer [ ] 18. Other [ ], specify…………………………………………………...

30. How much do you earn from the off-farm activities per annum (cedis) : ....

31. Do you receive any remittances? 1. Yes [ ] 0. No [ ] **If No skip to Q34**

32. How much remittance did you receive in the year 2014? ....

33. How much remittances do you give away in the year 2014?..

34. Does your household currently have any savings (bank, cash, etc.)? 1. Yes [ ] 0. No [**]** **If No skip Q36**

35. How much does your household currently have as savings?(cedis)…………………………

36. Do you own animals? 1. Yes [ ] 0. No [**]** **If no skip to Q38**

37. How many animals (Livestock) did you sell at the last season ?

Livestock	**Last season**		
	Number Sold	**Average Price per Head (GH₵)**	**Transportation and other marketing costs for the number you sold**
1. Cattle			
2. Sheep			
3. Goats			
4. Guinea Fowls			
5. Chicken			
6. Pigs			
7. Turkey			
8. Ducks			
9. Donkeys			
10. Other (specify)……………..			

38. What is your house built with? 1. mud and sticks [ ]   2. concrete[ ]   3. Bricks[ ]   (Enumerator: you can just look at the house and fill this without asking the farmer)

39. Distance from homestead to:

Items	Distance (km)
The nearest farm inputs stockist	
The nearest Extension service provider	
The nearest agriculture produces market	
The nearest credit provider	

SECTION C: *FIELD CROP PRODUCTION*

1. PLOT CHARACTERISTICS

40. How many plots do you have? ……………….

41. Please provide details concerning your production system

Plot ID	**41.a** Is this plot cultivated in the last season 2014? 1. Yes **(skip to Q41.c)** 0. No	**41.b** If not cultivated, Why? (**Key 1**)	**41.c** Size of the plot	**41.d** How did you acquire this plot? 1. Inherited 2. Purchased 3. Leased 4. Rent 5. Gift 7. Communal 8.Other………… ……………	**41.e** What is the fertility status of your plot? 1.Very fertile (very rich soil) 2. Fertile 3. Moderately (Fairly fertile) 4. Not fertile (marginal land)	**41.f** Do you practice irrigation? 1. Yes 0. No (**Skip to Q42)**	**41.g** what was the source of irrigation water? (**Key 3**)	**41.h** How many times did you irrigate the named crop field during the period of cultivation (**Key 4**)

			Units (**Key 2)**	Quantity					
Plot 1									
Plot 2									
Plot 3									
Plot 4									

Key 1
1. Fallow land
2. Marginal land
3. Other (specify)……………

Key 2
1. Acres
2 Hectares
3. Ropes
4. Poles

Key 3
1. privately owned well
2. privately owned river diversion
3. community owned irrigation system
4. government owned scheme
5. stream/river
6. other………….

Key 4
1. Once
2. Twice
3. Other (Specify………….)

2. INPUTS DATA

Input	**42.a** What crops did you grow on this plot last growing season 2014? (**Key5**)	**42.b** Total crop production		**42.c** **SEED**						**42.d** **FERTILISER**						**42.e** **AGROCHEMICALS**			
		Units **(Key6)**	Qty	Variety type (**Key7**)	Source of **seed** (**Key8**)	How much **seed** did you use?		What was the Price of **seed**?		Type of **fertilizer** **(Key9)**	Source of **fertilizer** (**Key8**)	What was the Quantity of **fertilizer**		What was the Price of **fertilizer** GHȻ		Type of agro chemical **(Key10)**	Source of agro chemic al **(Key8)**	What was the quantity of agro chemical	
						Unit **(Key6)**	Qty	Unit **(Key6)**	Price			Unit **(Key6)**	Qty	Unit **(Key6)**	Price			Unit **Key6**	Qty
Plot 1																			
Plot 2																			
Plot 3																			
Plot 4																			

42. Please provide information about your inputs used add output of crop

Key 5
1.Maize
2.Cassava
3.Rice
8. Sorghum
9. Tomato
10. Yam

Key 6
1.Kilogram
2. Jude Sack /Standard bag
3. Tuber
8. Packet
9. Pot
10. Set

Key 7
1. Traditional
2. Improved
3. Hybrid

Key 8
1. Own
2. Friends/Neighbours
3. Market

Key 9
1.NPK
2. SA (Amonia)
3.Urea

Key 10
1. Field pesticide
2. Weedicides
3. Storage pesticides

4.Okro	11. Beans	4. Basket	11. Gallon	4. Other (specify)	4. NGO Dev Project	4.Organic	4. None
5.Millet	12.Jatropha	5. Bowl	12. Liter		5. MOFA (Govt) Dev. Project	5. Jatropha seed cake	5. Other (specify)
6.Groundnut	13.Cotton	6. Box	13. Fanta bottle		6. counterpart		
7.Cowpeas	14.Other (Specify)	7. Dozen			7. Other (specify)		

43. Kindly provide the number, year of purchase and current price of the following capital items used during the last cropping season 2014.

Item	Hoes	Cutlass	Tractor/Power tiller	Knap-sack sprayer	Ox-plough	Ox-cultivation	Harrow	Other……..
Quantity								
Current price or rental cost								

3. CROP OUTPUT DATA

44. Provide details concerning your crop production of the last season 2014

44.a What crops did you cultivate last growing season? **(Key 11)**	44.b What is the total production of this crop last growing season?		44.c What was the per unit price of this crop last growing season?		44.d How do you use your harvest?		
	Units (**Key 12**)	Quantity	Units **(Key 12)**	Price	Consumption	Sold	
						Processed	Raw

Key 11
1. Maize 8. Sorghum

Key 12
1. Kilogram 7. Dozen

2. Cassava
3. Rice
4. Okro
5. Millet
6. Groundnut
7. Cowpeas
9. Tomato
10. Yam
11. Beans
12. Jatropha
13. Mango
14. Cotton
15. Other (specify)………

2. Jude Sack / standard bag
3. Tuber
4. Basket
5. Bowl
6. Box
8. Packet
9. Pot
10. Set
11. Crate

SECTION D: JATROPHA ADOPTION

1. JATROPHA GENERAL INFORMATION (Enumerator: explain Jatropha to the farmer)

45. Do you know Jatropha before now? 1. Yes[ ] 0. No [ ] **if no skip to Q72**

46. How did you hear about Jatropha? 1. Foreign investors [ ] 2.Neighbours [ ] 3.Village head/Village executive [ ] 4.Radio [ ] 5. Other farmers [ ]

6. Friends/Relatives [ ] 7. FBO 8.Others (specify)……..

47. Do you grow Jatropha? 1. Yes [ ] 0. No [ ] **if no skip to Q72**

48. What is the use of your Jatropha? (**Multiple responses**) 1. None [ ] 2. Selling of the seeds [ ] 3. Oil extraction at local level [ ] 4. Soap making [ ] 5.Manure [ ] 6. Live fencing [ ] g Medicinal purposes [ ] 8.Other specify…………………………………………………….

49. Do you get access to market to sell your Jatropha **last cropping season 2014**? 1. Yes [ ] **If Yes skip to Q51** 0. No [ ]

50. If you did not have access to market, Provide some reasons why 1. Lack of buyers [ ] 2. Lack of transport means [ ] 3. Could not meet market price [ ] 4. Could not meet market quality standards [ ] 5. Other [ ], specify………………………………………………………….

51. Provide information concerning your Jatropha production during the **last three years**

Year	**51.a** What is your Jatropha production?	**51.b** To whom do you sell your Jatropha? (**Key 14**)	**51.c** What was the per unit price of Jatropha?	**51.d** Quantity sold	**51.e** Quantity used at local level for oil extraction	**51.f** Quantity left (not

	Units**(Key 13)**	Quantity		Unit**(Key 13)**	Price	Unit**(Key 13)**	quantity	Unit**(Key 13)**	quantity	Unit**(Key 13)**	c
2014											
2013											
2012											

Key 13

1. Kilogram
2. Jude Sack / standard bag
3. Tuber
4. Basket
5. Bowl
6. Box
7. Dozen
8. Packet
9. Pot
10. Set
11. Crate

Key 14

0. Processing companies
1. Government processing companies
2. Nucleus growers
3. Exporters
4. Private individual
5. Other (specify)…………………..
6.

52. Did you acquire any property from Jatropha income? 1. Yes [ ] 0. No [ ] **If No skip to Q54**

53. Please list the acquired property ………………………………………………………………………………..

54. Do you belong to a Jatropha group? 1. Yes [ ] **If Yes skip to Q56** 0. No [ ]

55. Why do you not belong to a Jatropha group?..

56. Distance from homestead to the nearest Jatropha seed supplier (km)…………………………………

57. Why did you start growing Jatropha? (Multiple responses) 1. Diversify income sources [ ] 2. Own energy supply [ ] 3. Demarcating properties[ ] 4. Hedge for wind breaker[ ] 5. Rehabilitating degraded land [ ] 6. Stopping soil erosion[ ] 7. Producing fertilizers [ ] 8. Benefits from value added products from Jatropha[ ] 9. Other reasons (specify)…………………………………………………………………..

58. For how long have you been cultivating Jatropha? …..................................... years.

2. JATROPHA PLOT ALLOCATION

59. How many Jatropha plots do you have (number of plots where Jatropha is being grown)? …...

60. Provide information on your Jatropha plot allocation

	60.a What cultivation system do you grow Jatropha? **(Key 15)**	**60.b** Which portion (size) of this plot is allocated to Jatropha? (hectares)	**60.c** On which type of land do you grow Jatropha? (**Key 16**)	**60.c** What was the former use of your Jatropha plot? (**Key 17**)
Plot 1				
Plot 2				
Plot 3				

Key 15
1. Planted as a single crop on a whole field plot (monoculture)
2. Planted with and in between other crops (intercropping)
3. Planted as dividing rows between field plots (alley cropping)7
4. Planted on the sides of field plots (hedgerows)
5. Planted with tree crops like fruits ("agro forestry", horticulture)
6. Others (specify)…………………………………………………….

Key 16
1. Marginal land
2. fertile land
3. Other (specify)

Key 17
1. Marginal land
2. Fallow land
3. Food crops
4. Tree crops
5. Other(specify)…………………………………………

3. ***JATROPHA SUSTAINABILITY***

61. Which challenges do you face in Jatropha farming? (***multiple responses***) 1. Low germination rate [ ] 2. Shortage of inputs (planting material, fertilizers, pesticides,etc) [ ] 3. Pests and diseases [ ] 4. Low yields [ ] 5. Lack of technical support [ ] 6. Lack of market [ ] 7. Low seed price[ ] 8. Inadequate rainfall[ ] 9. Labour intensive [ ] 10. Inadequate water availability[ ] 11. Inadequate communication from the project developer [ ] 12.Insufficient support from the project developer [ ] Others(specify)…………………………………………………………

62. Please answer the following statements with respect to your activities.

	Strongly agree	agree	indifferent	disagree	Strongly disagree
Drought resistant (prevent desertification)					

Rehabilitating (restoring) your marginal land (improve soil quality)					
able to grow in low fertility soils with little nutrient supplementation or other care					
As hedges around garden, protects the crops against roaming animals like cattle or goats					
As hedges, reduces erosion caused by water and or wind					

63. What would you do with the land area cultivated with Jatropha if you would not grow Jatropha plants? 1. Planting of food crops[ ] 2. Holding animals on the land [ ] 3.Nothing 4.(fallow land) 5. marginal land (unused) [ ] 4. Other specify…………………..

64. Which other crops would you grow if you were abandoning your Jatropha cultivation? ………………………………………………………………………………………………………

65. Please provide reasons concerning the choice of these crops……….

66. Which animals would you keep if you were abandoning your Jatropha cultivation? ....

67. Please provide reasons concerning the choice of animals……

68. Would you be willing to extent the amount of land allocated to Jatropha? 1. yes [ ] 0. No[ ]

69. Please provide reasons ………………………………………………………

70. Do you plan continuing or discontinuing growing Jatropha cultivation? 1. Continuing [ ] 2. Discontinuing [ ]

71. Reasons for continuing or discontinuing growing Jatropha cultivation …………………………………………………………………………………… (**Skip to Section E**)

72.

72. a. Why are you not growing Jatropha? (Multiple responses) 1. Not aware [ ] 0. Not interested [ ] 3. No available land [ ] 4. No time [ ] 5.Do not know the use of the plant [ ]

6. No market [ ] 7. Others(specify)…………………………………………………………………………………………………

72.b Would you be willing to grow Jatropha**?** 1. Yes[ ] 0. No [ ]

72.c If yes which type of land would you be willing to grow Jatropha on? 1. Marginal land [ ] 2. Fertile land [ ] 3. Other (specify) [ ]

SECTION E. LABOUR ALLOCATION

73. Indicate the Family and Hired labour used on plot 1 during the last growing season?

Farm Activity on plot 1	**73.a** Hired labour					**73.b** Family labour			
	No. of persons			Wages/ day cedis	No. of Days	No. of persons			No. of Days
	M	F	CH			M	F	CH	
Land Preparation									
Nursery									
Ploughing									
Planting									
Weeding									
Pruning									
Fertilizer application									
Chemicals application									
Harvesting									
Drying									
Irrigation									
Other (Specify)…………………………………………………									

73.c

If the plot is intercropped with Jatropha, what proportion of labour do you assign to Jatropha cultivation? (in percentage)

1. 10%
2. 20%
3. 30%
4. 40%
5. 50%
6. 60%
7.70%
8. 80%
9. 90%
10. Other (specify)……………..

Where **M** =Adult male, **F**=Adult female and **CH**= Children (under 18 years)

74. Please indicate the Family and Hired labour used on plot 2 during the last growing season year?

<table>
<tr><td rowspan="3">Farm Activity on plot 1</td><td colspan="5">74.a
Hired labour</td><td colspan="4">74.b
Family labour</td><td rowspan="15">74.c
If the plot is intercropped with Jatropha, what proportion of labour do you assign to Jatropha cultivation? (in percentage)
1. 10%
2. 20%
3. 30%
4. 40%
5. 50%
6. 60%
7.70%
8. 80%
9. 90%
10. Other (specify)……………..</td></tr>
<tr><td colspan="3">No. of persons</td><td rowspan="2">Wages/ day cedis</td><td rowspan="2">No. of Days</td><td colspan="3">No. of persons</td><td rowspan="2">No. of Days</td></tr>
<tr><td>M</td><td>F</td><td>CH</td><td>M</td><td>F</td><td>CH</td></tr>
<tr><td>Land Preparation</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Nursery</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Ploughing</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Planting</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Weeding</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Pruning</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Fertilizer application</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Chemicals application</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Harvesting</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Drying</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Irrigation</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Other (Specify)…………………
……………………………</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Where **M** =Adult male, **F**=Adult female and **CH**= Children (< 18 years)

75. Please indicate the Family and Hired labour used on plot 3 during the last growing season year?

Farm Activity on plot 1	**75.a** Hired labour					**75.b** Family labour				**75.c** If the plot is intercropped with Jatropha, what proportion of labour do you assign to Jatropha cultivation? (in percentage) 1. 10% 2. 20% 3. 30% 4. 40% 5. 50% 6. 60% 7.70% 8. 80% 9. 90% 10. Other (specify)……………..
	No. of persons			Wages/ day cedis	No. of Days	No. of persons			No. of Days	
	M	F	CH			M	F	CH		
Land Preparation										
Nursery										
Ploughing										
Planting										
Weeding										
Pruning										
Fertilizer application										
Chemicals application										
Harvesting										
Drying										
Irrigation										
Other										

(Specify)………………… **……………………………**										

Where **M** =Adult male, **F**=Adult female and **CH**= Children (< 18 years)

76. Please indicate the Family and Hired labour used on plot 4 during the last growing season year?

Farm Activity on plot 1	**76.a** Hired labour					**76.b** Family labour				**76.c** If the plot is intercropped with Jatropha, what proportion of labour do you assign to Jatropha cultivation? (in percentage) 1. 10% 2. 20% 3. 30% 4. 40% 5. 50% 6. 60% 7.70% 8. 80% 9. 90% 10. Other (specify)……………..
	No. of persons			Wages/ day cedis	No. of Days	No. of persons			No. of Days	
	M	F	CH			M	F	CH		
Land Preparation										
Nursery										
Ploughing										
Planting										
Weeding										
Pruning										
Fertilizer application										
Chemicals application										
Harvesting										

Drying										
Irrigation										
Other (Specify)………………… ……………………………										

Where **M** =Adult male, **F**=Adult female and **CH**= Children (< 18 years)

SECTION F: EXPENDITURE OF THE HOUSEHOLD

77. Please provide information on your household expenditure

Item	Most regular Period of expenditure 1.Daily 2. Weekly 3.Monthly 4. Quarterly 5. Yearly 6. Termly	Expenditure (GH₵)	Main source of financing 1. Salary 2. Remittance 3. Sales of animals 4. Sales of crops in storage 5. Sales of crops just harvested 6. Income from Jatropha 7. Income from other tree crops 8. Income from cotton
77a. Food purchase (GH₵ /)			
77b. Water (GH₵ /)			
77c. Public toilet, (GH₵ /)			
77d. Sanitation – waste disposal (GH₵ /)			
77e. Education for children up to second cycle institutions (mainly uniform, books,, school fees & transport) (GH₵ /)			
77f. Health (GH₵ /)			
77g. NHIS (GH₵ /)			

77h. Rent (GH₵ /)			
77i.Travels (GH₵ /)			
77j. Funerals/social (GH₵ /)			
77k. Firewood/Charcoal (GH₵ /)			
77l. Electricity (GH₵ /)			
77m. Gas (GH₵ /)			
77n. Kerosene (GH₵ /)			
77o. Remittance (GH₵ /)			
77p. Others (specify)			

SECTION G: Food Insecurity experience scale of farmers

78. Please provide responses to these questions related to your food security status

(Recall period 12 months, measured at individual level, score based on first 8 questions while final 2 child questions used for context analysis.)	
Now I would like to ask you some questions about your food consumption in the last 12 months. **During the last 12 MONTHS, was there a time when:**	
78.a You were worried you would run out of food because of a lack of money or other resources?	0 No 98 Don't Know 1 Yes 99 Refused
78.b You were unable to eat healthy and nutritious food because of a lack of money or other resources?	0 No 98 Don't Know 1 Yes 99 Refused

78.c You ate only a few kinds of foods because of a lack of money or other resources?	0 No 98 Don't Know 1 Yes 99 Refused
78.d You had to skip a meal because there was not enough money or other resources to get food?	0 No 98 Don't Know 1 Yes 99 Refused
78.e You ate less than you thought you should because of a lack of money or other resources?	0 No 98 Don't Know 1 Yes 99 Refused
78.f Your household ran out of food because of a lack of money or other resources?	0 No 98 Don't Know 1 Yes 99 Refused
78.g You were hungry but did not eat because there was not enough money or other resources for food?	0 No 98 Don't Know 1 Yes 99 Refused
78.h You went without eating for a whole day because of a lack of money or other resources?	0 No 98 Don't Know 1 Yes 99 Refused
78. i Do you have children < 5 years of age (if yes continue; if no stop here)	0 No 1 Yes
During the last 12 MONTHS, was there a time when any of the children younger than 5 years old:	
78.j CHILD Q1. Did not eat healthy and nutritious foods because of a lack of money or other resources?	0 No 98 Don't Know 1 Yes 99 Refused
78.k CHILD Q2. Was not given enough food because of a lack of money or other resources?	0 No 98 Don't Know 1 Yes 99 Refused

SECTION H: CONTRACT PREFERENCES

1. CONTRACT INFORMATION ON THE FIELD

79. Did you sign a contract to produce Jatropha? 1. Yes [ ] 0. No [**]** **if no skip to Q84**

80. Who were the contractors? 1. processing companies[ ] 2.government processing company [ ] 3. nucleus growers[ ] 4. exporters [ ] 5. Private individual [ ]

6. Others(specify)……………….

81. Please provide details about the contract terms with your counterpart

81.a	81.b	81.c	81.d	81.e	81.f
Did you have a written contract? 1. Yes 0. No	Did you have a renegotiation option? 1. Yes 0. No	Did you receive Jatropha seed from your counterpart (buyer) 1. Yes 0. No	Did you receive pesticides and fertilizers from your counterpart(buyer) 1. Yes 0. No	Did you receive technical training from your counterpart(buyer) 1. Yes 0. No	What was the technical training about? **(Key 18)**

Key 18

1. Jatropha planting techniques
2. Jatropha pruning and weeding techniques
3. Jatropha pest controls
4. Jatropha Harvesting techniques
5. Storage techniques
6. Others(specify)………………

82. Did you have other contracts terms that I did not non mention? 1. Yes [ ] 0. No [ ]

83. Please which ones? 1. Contract length [ ] 2. Others (specify)……………………………………………………………..

84. Would you be willing to enter into contract to produce Jatropha? 1. Yes [ ] 0. No [ ]

85. Please provide reasons…………………………………………………………………..

2. CHOICE EXPERIMENT

86. Carefully examine the contracts. Then please tell me which contract alternative you would prefer most for Jatropha cultivation or prefer to maintain your current crop mix

	Contract type	Price Setting	Support from buyer	Renegotiation option	I would choose:

86.a Contract A	Written Contract 	GH₵ 1/kg	Seed, Fertilizers &Pesticides Only 	No	○
86.b Contract B	No Written Contract 	GH₵ 1.5/kg	Seed, Technical training, Fertilizers&Pesticides 	No	○
86.c No Contract	**I would not grow Jatropha under the offered contracts and would maintain my current crop mix**				○

87. Pretend that the contracts you saw before are no longer available and that these two contracts are the only two you are considering. Which, if either, would you prefer?

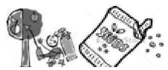
	Contract type	**Price Setting**	**Support from buyer**	**Renegotiation option**	**I would choose:**
87.a Contract C	Written Contract 	GH₵ 1.5/kg	Seed, Technical training Only 	Yes	○
87.b Contract D	Written Contract 	GH₵ 0.5/kg	Seed, Technical training Only 	Yes	○

87.c No Contract	**I would not grow Jatropha under the offered contracts and would maintain my current crop mix**	○

88. Pretend that the contracts you saw before are no longer available and that these two contracts are the only two you are considering. Which, if either, would you prefer?

	Contract type	**Price Setting**	**Support from buyer**	**Renegotiation option**	**I would choose:**
88.a Contract E	No Written Contract 	GH₵ 1/kg	Seed, Technical training Only 	No	○
88.b Contract F	Written Contract 	GH₵ 0.5/kg	Seed, Technical training, Fertilizers&Pest &Pesticides 	Yes	○
88.c No Contract	**I would not grow Jatropha under the offered contracts and would maintain my current crop mix**				○

89. Pretend that the contracts you saw before are no longer available and that these two contracts are the only two you are considering. Which, if either, would you prefer?

	Contract type	**Price Setting**	**Support from buyer**	**Renegotiation option**	**I would choose:**
89.aContract G	Written Contract 	GH₵ 0.5/kg	Seed,Fertilizers &Pesticides Only 	No	○

89.b Contract H	No Written Contract 	GH₵ 1/kg	Seed Only 	Yes	○
89.c No Contract	**I would not grow Jatropha under the offered contracts and would maintain my current crop mix**				○

90. Pretend that the contracts you saw before are no longer available and that these two contracts are the only two you are considering. Which, if either, would you prefer?

	Contract type	Price Setting	Support from buyer	Renegotiation option	I would choose:
90a. Contract I	No Written Contract 	GH₵ 0.5/kg	Seed, Technical training Only  	No	○
90.b Contract J	Written Contract 	GH₵ 0.5/kg	Seed Only 	No	○
90.c No Contract	**I would not grow Jatropha under the offered contracts and would maintain my current crop mix**				○

91. Pretend that the contracts you saw before are no longer available and that these two contracts are the only two you are considering. Which, if either, would you prefer?

	Contract type	Price Setting	Support from buyer	Renegotiation option	I would choose:
91.a Contract K	No Written Contract 	GH₵ 0.5/kg	Seed,Fertilizers &Pesticides Only 	Yes	○
91.b. Contract L	No Written Contract 	GH₵ 0.5/kg	Seed Only 	Yes	○
91.c No Contract	**I would not grow Jatropha under the offered contracts and would maintain my current crop mix**				○

92. Pretend that the contracts you saw before are no longer available and that these two contracts are the only two you are considering. Which, if either, would you prefer?

	Contract type	Price Setting	Support from buyer	Renegotiation option	I would choose:
92.a Contract M	No Written Contract 	GH₵ 0.5/kg	Seed, Technical training, Fertilizers&Pesticides 	No	○
92.b Contract N	Written Contract	GH₵ 1.5/kg	Seed Only 	No	○

					
92.c No Contract	**I would not grow Jatropha under the offered contracts and would maintain my current crop mix**				○

93. Pretend that the contracts you saw before are no longer available and that these two contracts are the only two you are considering. Which, if either, would you prefer?

	Contract type	**Price Setting**	**Support from buyer**	**Renegotiation option**	**I would choose:**
93.a Contract O	No Written Contract 	GH₵ 1.5/kg	Seed,Fertilizers &Pesticides Only 	Yes	○
93.b. Contract P	Written Contract 	GH₵ 1/kg	Seed, Technical training, Fertilizers&Pesticides 	yes	○
93.c. No Contract	**I would not grow Jatropha under the offered contracts and would maintain my current crop mix**				○

SECTION I: Risk and time preferences

94. Self-Assessment risk elicitation

The self-assessment question asked the participants to assess their attitudes toward accepting risk on a scale of 0 to 10, defined over highly risk averse to highly risk seeking attitudes.

How do you see yourself: Are you in general a person who takes risk or do you try to avoid risks? Please self-grade your choice (ranging between 0-10), where the grades run from 0: “not at all prepared to take risk” to 10: “very much prepared to take risk”.The same question has been asked for five domains:

	0	1	2	3	4	5	6	7	8	9	10

General											
Agriculture											
Finance											
Health											
Education											

95. Psychometric risk attitude elicitation

Please answer the following statements with respect to your activities.

	Strongly agree	agree	indifferent	disagree	Strongly disagree
I do not rely only on my production					
I complement my farm income with off-farm income					
I have some of my assets in liquid (cash) form					
By my experience I engage in only less risky enterprise					
I obtain marketing information before sales of my farm produce					
I am never among the first producers in my area to adopt new technology					
Off-farm investments are important sources of income for me.					
I always store my production to anticipate good price					
I invest a lot in my farm (buying improved seeds and fertilizers…)					
More than 50% of my farm productions is for my own consumption					

96. Time preferences

96.a	Which of the following choices would you prefer: (1) Receive 10 GH¢ today. OR (2) Receive 15 GH¢ in one month.	1. Option (1) 2. Option (2)
96.b	Which of the following choices would you prefer: (1) Receive 10 GH¢ in 6 months. OR (2) Receive 15 GH¢ in 7 months.	1. Option (1) 2. Option (2)

97. Risk perceptions

Which of your current crop is most likely to be substituted with Jatropha?

What yield do you consider most likely for your current crop during the next harvest period?

What do you expect will be your lowest yield during the next harvest period?

What do you expect will be your highest yield likely during the next harvest period?

What price do you anticipate to be the most likely "current crop" price during the next harvest period?

What price do you anticipate to be the lowest possible "current crop" price during the next harvest period?

What price do you anticipate to be the highest possible "current crop" price during the next harvest period?